Operational Test and Evaluation (OT&E) Performance, Integration and Operational Tests of the Mode S Beacon (Enroute Configuration) Final Report

Andrew Leone

February 1998

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16. Abstract
This document reports the findings of the performance and operational evaluation tests conducted on the Mode Select (Mode S) Beacon System, in a full Mode S mode, enroute configuration collocated with a Common Digitizer Model-2 (CD-2) and Air Route Surveillance Radar (ARSR) system. The tests were conducted at the Federal Aviation Administration (FAA) William J. Hughes Technical Center and at the enroute Mode S keysite located at the St. Albans, Vermont, long-range radar facility in conjunction with Boston Air Route Traffic Control Center (ARTCC), located in Nashua, New Hampshire. The Mode S systems under test were fully configured, dual-channel systems having all required external interfaces connected to actual National Airspace System (NAS) equipment, with the exception of the Maintenance Processor Subsystem (MPS), which was not ready for integration with the Mode S at the time of these tests. A combination of system optimization, surveillance performance and operational suitability testing were performed as part of this Operational Test and Evaluation (OT&E) effort. Test goals were to ensure proper operation of the Mode S sensor in Mode S mode of operation for an enroute configuration, while integrated with appropriate NAS equipment.

The tests were conducted in accordance with procedures for OT&E stated in FAA Order 1810.4B. The format of this test report is in accordance with FAA-STD-024b.

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EXECUTIVE SUMMARY

The Mode Select Beacon System (Mode S) Enroute Performance and Operational Test and Evaluation (OT&E) was conducted at the Federal Aviation Administration (FAA) William J. Hughes Technical Center, with subsequent key site testing at St. Albans, Vermont, and Boston Air Route Traffic Control Center (ARTCC) at Nashua, New Hampshire. The Mode S system under test at the FAA Technical Center was configured to support enroute field configurations. This configuration allows for up to 255-mile coverage, a target load of 700 beacon aircraft, a data link communications load of 100 percent of the full Mode S specification requirements, and a collocated Air Route Surveillance Radar (ARSR)-2 with a Common Digitizer (CD)-2. The Mode S software versions used during the OT&E effort were TE00.1 through TE00.5.

Testing was conducted using the two Mode S configurations needed to support the enroute field configurations in the field; the Mode S/CD-2/ARSR configuration and the Mode S Beacon Only configuration, though this latter configuration was only tested in limited areas. Both Mode S configurations were interfaced to both ARTCC configurations; Host Computer System (HOST)/Direct Access Radar Computer (DARC)/Computer Display Channel (CDC) and HOST/DARC/Display Channel Complex (DCC). The Mode S/CD-2/ARSR configuration provides radar/beacon merged, correlated and uncorrelated beacon only, and uncorrelated radar only targets, as well as weather information, to the HOST/DARC/(CDC or DCC) configuration. The Mode S Beacon Only configuration provides correlated and uncorrelated beacon only targets to the HOST/DARC/(CDC or DCC). The HOST software used was A4E12 and the DARC software was RAM010A.

The performance baseline was established for the Mode S system by conducting a series of tests which focus on surveillance performance. This new baseline is built upon the terminal baseline data to verify proper system operation in either configuration. It will be used as a comparison tool with future Mode S upgrades that will be deployed at both terminal and enroute configurations.

There were no major anomalies in the performance testing. Integration was the most prevalent problem area. Appendix A, the Mode S Enroute OT&E Issues Matrix, summarizes the issues identified by this OT&E. These issues are categorized as Major, Moderate, and Minor. Proposed solutions are provided. Appendix B provides a reconciliation of all the requirements allocated to the performance and enroute integration OT&E.

As a result of the OT&E effort, there was one major deficiency with the Mode S system which would only impact its deployment to the enroute beacon only sites. A maintenance release of the system software will have to be issued to resolve search Real Time Quality Control (RTQC) deficiencies before beacon only deployment can be achieved. Though identified as a moderate issue, radio frequency interference (RFI) conditions at some enroute radar sites may also be a problem, especially Fixed Position Search (Radar) (FPS) sites and facilities with commercial radio frequency (RF) transmission towers in close proximity. These conditions may require additional RFI isolation of the Mode S and its peripheral subsystems.

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There are a number of items addressed that should be implemented to improve system performance and maintainability. These include incorporating terminal baseline changes, which correct outstanding issues related to the Terra algorithm, Mode S transponder Flight Status bit fixes, and other areas which have been identified in terminal systems.

1. INTRODUCTION.

The purpose of this final report is to provide results from the Operational Test and Evaluation (OT&E) of the Mode Select Beacon System (Mode S) in an enroute configuration. This report will provide analysis in the major areas of test along with any information related to observation and situations that were encountered during the testing which may have an impact on implementing full Mode S at enroute sites nationally. The primary areas of testing included performance, integration, and operational evaluation.

Formal OT&E testing commenced in October 1995, with version TE00.1, and was concluded in October 1996, with version TE00.5. Performance testing was conducted at the Federal Aviation Administration (FAA) William J. Hughes Technical Center's enroute radar test facility located in Elwood, New Jersey. Integration and operational testing was conducted at both the Technical Center and at the designated key site; St. Albans, Vermont, long-range radar site and the Boston Air Route Traffic Control Center (ARTCC) located in Nashua, New Hampshire. In addition, a performance analysis comparing Mode S/Interim Beacon Initiative (IBI) operation with a National Aviation Facilities Experimental Center (NAFEC) Dipole Feed (NADIF) and Open Array antenna was done utilizing two reports generated from testing conducted at the Parker, Colorado (QPK), long-range radar site in December 1994 and April 1996, respectively.

This report addresses primarily the Mode S interim single-face enroute configuration applicable to Air Route Surveillance Radar (ARSR)-1/2 and Fixed Position Search (Radar) (FPS) sites. Some simulated testing was conducted in the Beacon Only configuration. National Airspace System (NAS) level integration was tested only to the Host Computer System (HOST)/Direct Access Radar Computer (DARC) Computer Display Channel (CDC)/Display Channel Complex (DCC) configurations. In addition, data link was tested only at the performance level to verify specification compliance and to establish a baseline.

2. REFERENCE DOCUMENTS.

The following documents are referenced in this report:

SPECIFICATIONS	
FAA-E-2716	Mode Select Beacon System (Mode S) Sensor, Amendment 2, Changes 1-24, SCN #18 as changed by Mod 32 and Mod 38 contract
NAS-SS-1000	NAS System Specification, Functional and Performance Requirements for the National Airspace System
FAA-RD-80-14A	The Mode Select (Mode S) Surveillance and Communications, ATC and Non-ATC Link Protocols, and Messages – July 12, 1985
TM-PA-0018/074/03	Mode S to Common Digitizer (Model 2) Interface Control Document for Mode S Beacon System Sensor – April 14, 1995

TM-PA-0018/075/02A	Mode S/ATC Surveillance Link to ATC Enroute Facilities Interface Control Document for Mode S Beacon System Sensor - March 23, 1987

<u>STANDARDS</u>

FAA-STD-024B	Preparation of Test and Evaluation Documentation – August 17, 1987

<u>FAA ORDERS</u>

1810.4B	FAA NAS Test and Evaluation Program
6365.3	Maintenance of the Mode Select (Mode S) Beacon System

<u>PLANS</u>

DOT/FAA/CT-TN 88/28	Mode S Master Test Plan
DOT/FAA/CT-TN 89/24	Mode S Performance Test Plan
DOT/FAA/CT-TN 89/51	Mode S Operational Test and Evaluation/Integration Test Plan

<u>PROCEDURES</u>

DOT/FAA/CT-TN 91/41	Interim Terminal Mode S/NAS Configurations Operational Test and Evaluation (OT&E)/Integration Test Procedures
	Mode S Performance Test Procedures (Category 1) – February 28, 1992 (Modified May 30, 1995)

<u>REPORTS</u>

DOT/FAA/CT-ACW100 93/59	Mode S Terminal Configuration Operational Test & Evaluation (OT&E) Operational and OT&E Integration Tests Quick Look Report – September 10, 1993
DOT/FAA/CT-TN 95/7	Mode S Enroute OT&E Quick Look Report – November 7, 1996
DOT/FAA/CT-TN 95/61	Mode S OT&E Enroute IBI Operation
	Mode S Beacon System Terminal Configuration Performance Test Report - May 1995
	Operational Test and Evaluation Mode S Beacon System Terminal Configuration Preliminary Test Report - April 1994
	Parker (QPK) Optimization Proceedings of Mode S En Route Antenna including Flight Check Performance – May 8, 1996

Quick Look Report on Capacity Throughput, ARTS-3A Surveillance Performance, and Mode S Surveillance Performance

TR21.4.3.2 OT&E Results and Analysis

Testing on TR21.4.3 Software for Correlating Users

USER'S MANUALS

NASP-9247-P02 Data Analysis and Reduction Tool (DART) – August 16, 1993

3. SYSTEM DESCRIPTION.

3.1 BACKGROUND.

The enroute Mode S baseline is built upon the current terminal baseline, and has been kept up to date with maintenance releases to the terminal national baseline through release SAR214C. The final enroute build will eventually become the national baseline and be incorporated at both enroute and terminal facilities. The fundamental difference in the two baselines is outlined below.

a. User adaptable range coverage mapping out to 255 nautical miles (nmi).

b. Target capacities and data link loading meet specification requirements.

c. Remote Maintenance Monitoring System (RMMS) interface complies with the Maintenance Processor Subsystem (MPS)-to-Mode S Remote Maintenance Subsystem (RMS) Interface Control Document (ICD) (NAS-IC-51003406, March 1995, Version 4).

d. Incorporation of Mode S-to-Common Digitizer (CD)-2 interface, which includes the digital interface between the two systems, the surveillance data selector (SDS) switch, and an enhanced independent Air Traffic Control Radar Beacon System (ATCRBS) board.

e. Overlapped Mode S/ATCRBS all-call interrogation scheme, processing both the Mode S only and classic ATCRBS interrogations within the same listening window.

f. Enroute dissemination functionality.

g. Surveillance line data overload throttling capabilities.

3.2 TEST SYSTEM CONFIGURATION.

The primary test system used was located at the Technical Center's long-range radar test facility located in Elwood, New Jersey. The Mode S was integrated with a collocated CD-2 and ARSR-2. The facility was already upgraded with the Mode S enroute back-to-back antenna, 7-path rotary joint and the new Fixed Ground Antenna Radome (FGAR).

Prior to the start of performance and integration testing, the Mode S was optimized for power, antenna tilt, and sensitivity timing control (STC). The resultant output power at the input to the antenna was optimized to 250 W (directional)/500 W Side-Lobe Suppression (SLS). The STC was set to 49 decibels (dB) and the tilt was adjusted to -0.5°. It was also determined that to ensure adequate probability of detection (Pd) of weaker transponders in the coverage volume, especially out to 255 nmi, the receiver threshold was lowered 3 dB to -82 decibels below the level of a milliwatt (dBm).

The Mode S was connected to the NAS automation equipment via Codex digital modems multiplexed onto a T1 line. Within the Technical Center NAS test facility, the data is distributed through a Bytex switching matrix to the available Peripheral Adapter Module Replacement Item (PAMRI), HOST, CDC/DCC, and DARC systems.

4. PERFORMANCE TESTING.

The performance tests conducted as part of the enroute OT&E were based on the performance tests used to validate the terminal Mode S baseline. A surveillance baseline was established using the Aircraft Reply and Interference Environment Simulator (ARIES) to simulate aircraft and False Replies Unsynchronized in Time (FRUIT), followed by an evaluation of coverage and false target elimination when using an open array antenna collocated with an ARSR-2. The primary differences between the terminal and enroute are in the target capacities, coverage range, and scan rate. Target capacity for the enroute was brought up to the full 700 target capacity defined in the Mode S specification, along with the specified data link loading. Coverage range of the system extends out to 255 nmi at scan rates between 9.6 and 12.0 seconds per revolution. Some of the testing conducted as part of the terminal OT&E and enroute IBI OT&E were not repeated. In addition, live world targets of opportunity were used extensively in place of controlled test aircraft, as utilized during the terminal OT&E. This was done to better characterize and baseline the test system in a way that any other enroute system can compare with live data collections and off-line software analysis.

4.1 IBI NADIF VERSUS OPEN ARRAY ANTENNA COMPARISON.

4.1.1 Purpose.

This test compared the performance of an operational enroute Mode S operating in IBI mode with a NADIF antenna configuration versus a Mode S enroute high gain back-to-back open array. The test data used for this comparison was taken from the Mode S enroute IBI OT&E testing conducted at the Parker, Colorado, radar facility and the site optimization data compiled by ANM-450 used to commission the open array at the same facility.

4.1.2 Test Objectives.

The objectives of this test were to provide a comparison of Mode S/IBI performance when operated on the Mode S Enroute Open Array antenna versus the NADIF antenna. A number of enroute Mode S sites are configured for an interim period of time on the NADIF antenna while awaiting radome/open array installation, optimization, flight check, and commissioning. Since the IBI mode is used as a backup to all Mode S operations, it was important to characterize performance with both antenna configurations.

4.1.3 Test Configuration.

Two antenna configurations were implemented for this: (1) the NADIF antenna configuration, and (2) the Mode S Enroute Open Array antenna. The Mode S operated exclusively in the IBI mode, and beacon processing in this configuration is performed by the CD-2.

4.1.4 Test Description.

Once the Mode S was optimized in each antenna configuration, multiple data collections were collected for baselining the system utilizing targets of opportunity. These data collections were conducted over multiple days during the test periods.

4.1.5 Data Analysis.

Radar Beacon Analysis Tool (RBAT) programs Beacon False Target Analysis (BFTA), Surveillance Analysis (SA), and Permanent Echo Accuracy (PEA) were executed on each of the sets of data. The data sheets compiled for each report provided ample data to provide a comparison. Six data runs from each configuration were used and are tabulated in appendix E. The analysis given by the reports provides surveillance performance, false target summaries, and fixed target accuracy.

4.1.6 Test Results.

The data tabulated for each configuration was averaged together and then graphed. Figures 4.1.6-1, 4.1.6-2, and 4.1.6-3 depict the false target, surveillance, and accuracy analysis characteristics, respectively.

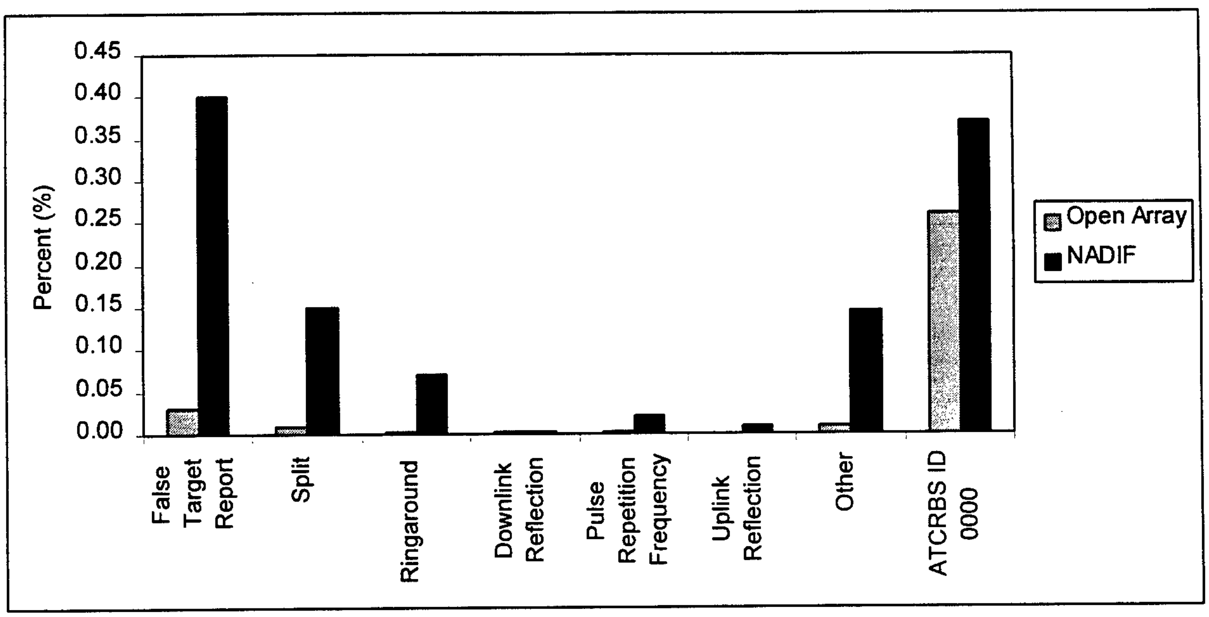


FIGURE 4.1.6-1. BEACON FALSE TARGET STATISTICS, OPEN ARRAY VERSUS NADIF ANTENNA

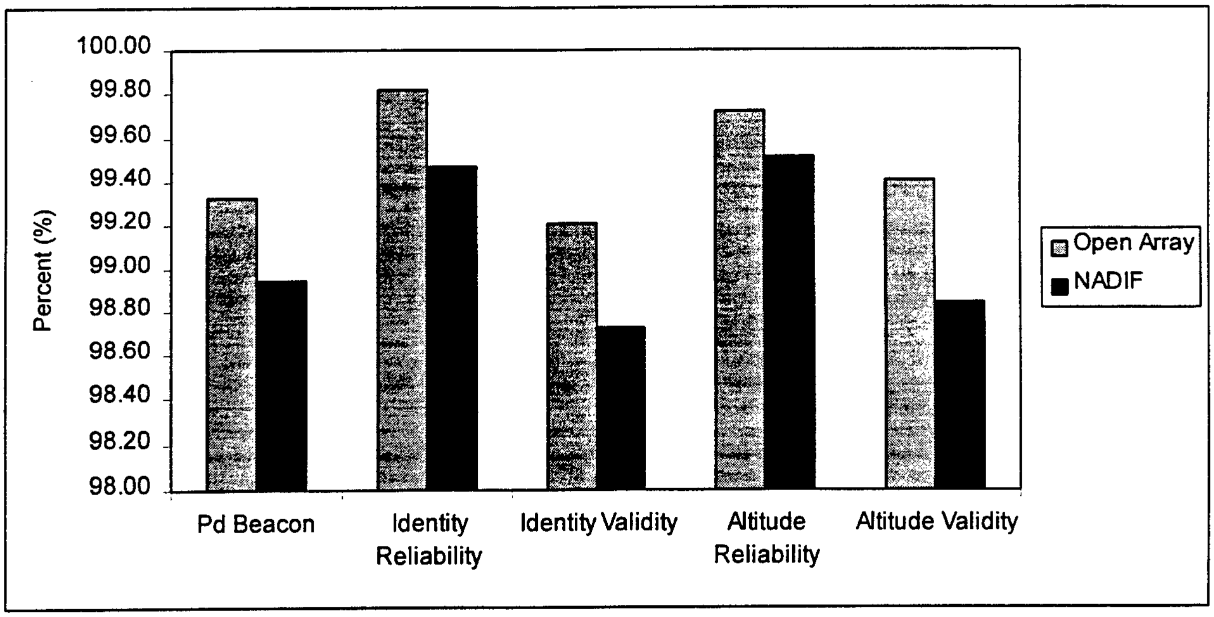


FIGURE 4.1.6-2. SURVEILLANCE STATISTICS, OPEN ARRAY VERSUS NADIF ANTENNA

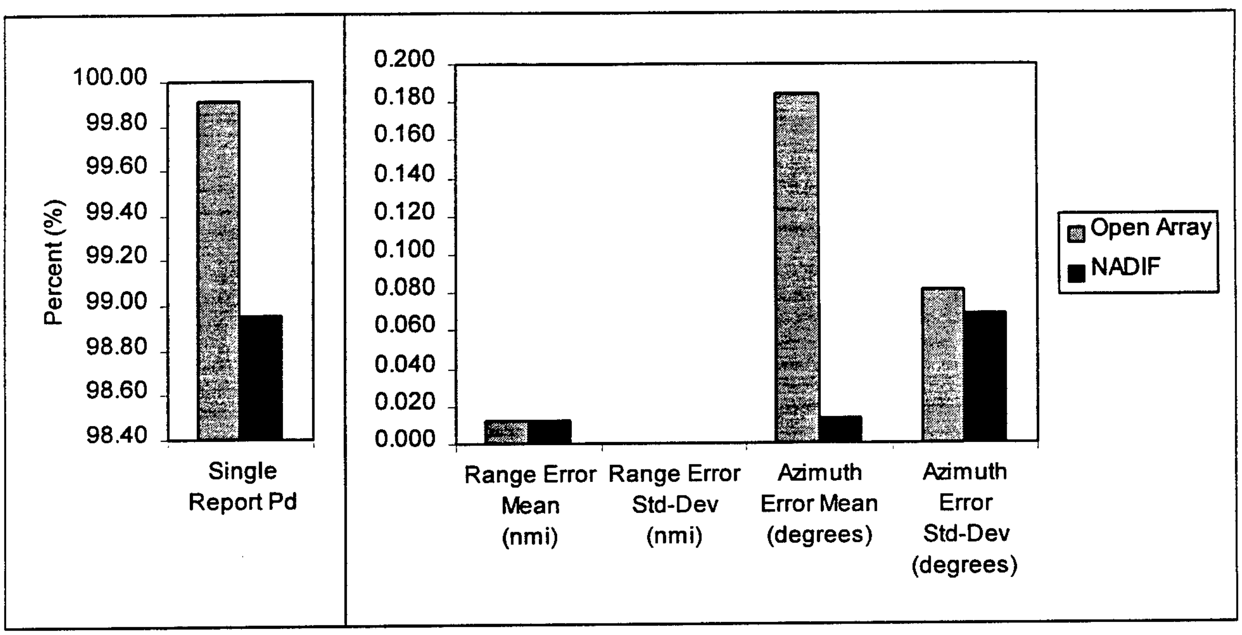


FIGURE 4.1.6-3. PERMANENT ECHO ACCURACY, OPEN ARRAY VERSUS NADIF ANTENNA

4.1.7 Conclusions.

Overall the Mode S/IBI performance characteristics improved in all areas, with the exception of azimuth error, specifically the small increase in azimuth error which could be a result of the wider beam width of the open array and the sliding window detector algorithm employed by the

CD-2. The mean azimuth error is a result of a fixed bias between the open array and NADIF configurations, i.e., the CD-2 was not realigned to compensate for the two Azimuth Change Pulse (ACP) difference caused by either mechanical or electrical centering of the antenna's boresight. The improved surveillance can be attributed to the added run length, which averaged 31 for the NADIF and 46 for the open array. There is also a significant reduction in the false target statistics across all categories, possibly due to the improved beam characteristics of the open array antenna.

4.2 SURVEILLANCE BASELINE – Pd AND Pfa.

4.2.1 Purpose.

This test measured the Mode S Pd and probability of false alarm (Pfa), both as a function of radio frequency (RF) signal level and FRUIT level. This section includes the results and analysis of data observed using no FRUIT, moderate FRUIT, intermediate FRUIT, and heavy FRUIT scenarios. These baseline tests establish performance using controlled, simulated targets, and FRUIT generated by the ARIES Simulator.

4.2.2 Test Objectives.

The objectives for this test were as follows:

a. To verify that the Mode S Pd and the ATCRBS Pd rates exceed 99 percent for a received power of -76 dBm in the absence of FRUIT.

b. To verify that the Mode S Pfa and the ATCRBS Pfa are less than 10^{-6}, while detecting targets in the absence of RF interference.

c. To establish a baseline of Pfa versus selected FRUIT levels.

d. To establish a baseline of Pd versus selected RF signal levels and FRUIT levels.

4.2.3 Test Configuration.

Figure 4.2.3-1 depicts the configuration for this test.

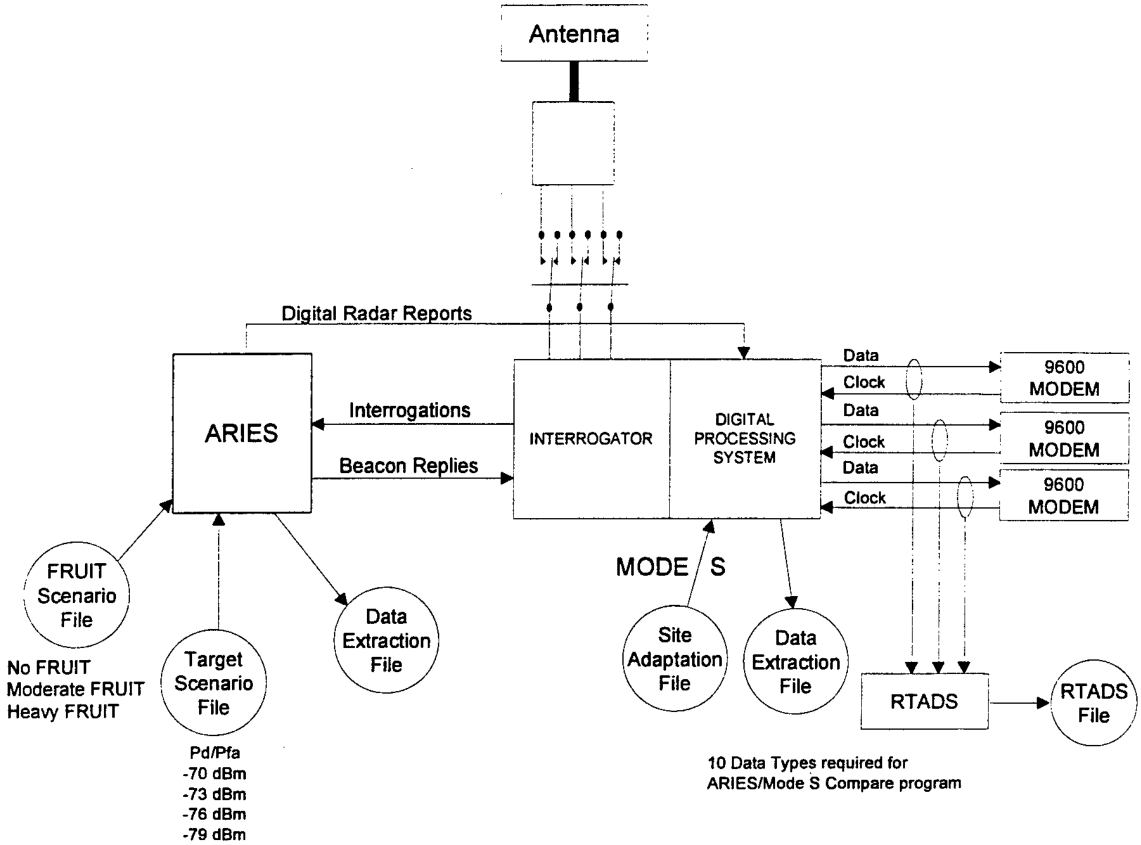


FIGURE 4.2.3-1. SURVEILLANCE BASELINE Pd/Pfa

4.2.4 Test Description.

It was necessary to calibrate the ARIES to validate the received reply power levels -70, -73, -76, and -79 dBm for use in this test. The sensor was operated with a dummy load, rather than the antenna, for this test.

Each subtest executed an ARIES scenario with ATCRBS and Mode S targets using a single received power level and one FRUIT level. There were four different received power levels and three different FRUIT levels; no FRUIT, moderate FRUIT (4 kilos (k)/second (sec)), and heavy FRUIT (40 k/sec). It required 12 subtests to run every combination of received power level and FRUIT level.

The ARIES Site Adaptable Parameter (SAP) configuration was used with the following modifications:

a. STC disabled.

b. ARIES beam shaping disabled (10-dB sum signal rolloff from the antenna boresight).

Each of the ARIES scenarios started with 5 rings of 32 targets per ring. Each ring is 50 nmi apart starting at a range of 5 nmi from the sensor, with each target within a ring equally spaced, 11.25° apart. There were 16 ATCRBS and 16 Mode S targets, alternating ATCRBS target, Mode S target, ATCRBS target, Mode S target, and so forth around each of the rings until it was complete.

Each scenario started with each target moving at a constant clockwise (cw) rotation rate, about the sensor, with its range increasing at a constant rate, and an approximate ground speed of 240 nmi per hour. The scenario ended after 10 minutes. At the end, each target was at a sensor range of 40 nmi beyond its start range, and had rotated 5.625° cw from its starting location.

For the execution of the Pfa tests, ARIES was run with a no-target scenario in each case. The FRUIT levels for each test varied through the following definitions:

a. No FRUIT
b. Moderate FRUIT (4 k/sec ATCRBS, 50/sec Mode S)
c. Intermediate FRUIT (20 k/sec ATCRBS, 100/sec Mode S)
d. Heavy FRUIT (40 k/sec ATCRBS, 200/sec Mode S)

Each test ran for 10 minutes, with data recorded at the Mode S and the Real-Time Aircraft Display System (RTADS).

4.2.5 Data Analysis.

ARIES and sensor data extraction files were saved from each subtest. These data files were reduced with the ARIES/Mode S Compare program, which computed sample size, Pd (also called blip/scan ratio), identity (ID) reliability, altitude reliability, number of uncorrelated reports, and the number of replies per report.

RTADS data extraction files were also saved from each subtest. These data files were used by the SA program to compute sample size, blip/scan ratio, and code reliability.

The method used to determine a Pfa in order to characterize the system's false target susceptibility in various FRUIT environments centers on the premise that there were no real targets generated in each of the scenarios, thus all target reports generated were by default false. The total number of reports generated for each test was divided by the time duration of the scenario.

4.2.6 Test Results.

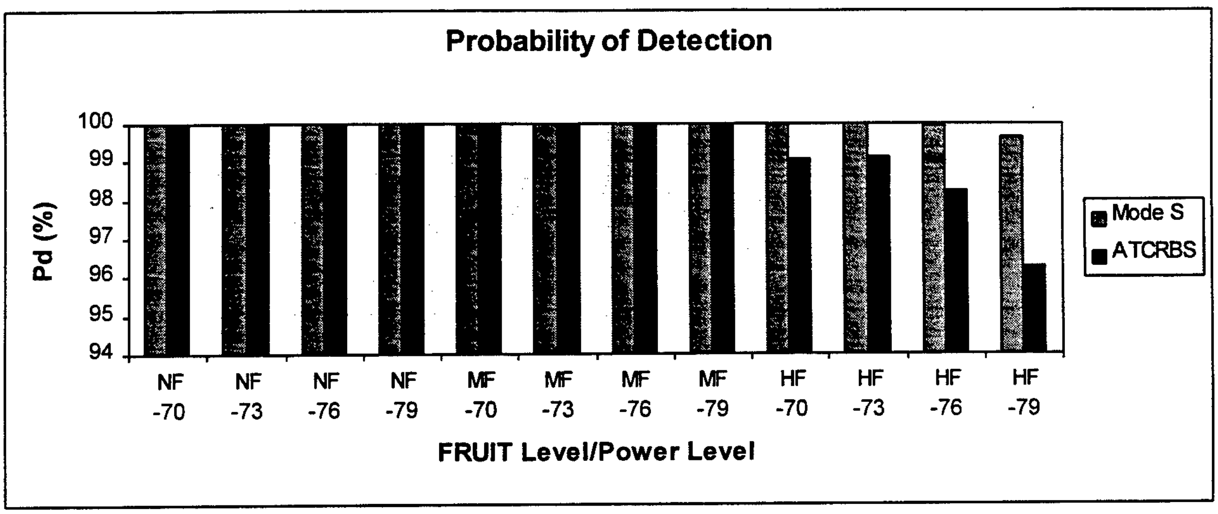
The data presented was generated by processing the Mode S sensor, ARIES, and RTADS data extraction files using the Data Reduction (DR) and the RBAT programs. Specifically, the DR option ARIES/Mode S Compare was used to process the sensor and ARIES extraction data, and the RBAT Beacon False Target Summary (BFTS) and SA were used to process the RTADS extraction data.

Objective 1 required that the Pd for Mode S and ATCRBS targets exceed 99 percent for received reply power of -76 dBm (in the absence of FRUIT). All subtests passed. These results are shown in table 4.2.6-1.

TABLE 4.2.6-1. PROBABILITY OF DETECTION

Subtest	Description	Pd Mode S (%)	Pd ATCRBS (%)
1	-70 dBm, No FRUIT	100.00	100.00
2	-73 dBm, No FRUIT	100.00	100.00
3	**-76 dBm, No FRUIT**	**100.00**	**100.00**
4	-79 dBm, No FRUIT	100.00	100.00
Pd Limits		>99.00	>99.00
Limits Met?		Yes	Yes

Figure 4.2.6-1 details the sensor's Pd performance as a function of decreasing received power levels and increasing FRUIT levels. Note from this figure that Mode S performance is virtually unaffected by the adverse conditions while ATCRBS performance is degraded at heavy FRUIT level.



Legend:
NF = No FRUIT
MF = Moderate FRUIT (4 k/sec ATCRBS, 50/sec Mode S)
HF = Heavy FRUIT (40 k/sec ATCRBS, 200/sec Mode S)
Power levels are expressed in dBm.

FIGURE 4.2.6-1. PROBABILITY OF DETECTION FOR ATCRBS/MODE S TARGETS

Objectives 2 and 3 required the establishment of a Pfa for a no FRUIT level environment and a baseline of false target operational values for a selected range of FRUIT levels, respectively. The test results shown in table 4.2.6-2 fulfill this objective.

TABLE 4.2.6-2. PROBABILITY OF BEACON FALSE TARGETS

Subtest Number	False Targets/second	FRUIT Level
13	0 *	No FRUIT
14	.002	Intermediate
15	.17	Moderate
16	1.23	Heavy

* Pfa was well below 10^{-6} required level for the zero FRUIT case.

Objective 4 required the establishment of a baseline of Pd operational values for a selected range of receiver power and FRUIT levels. The test results shown in table 4.2.6-3 fulfill this objective.

TABLE 4.2.6-3. Pd BASELINE

	Probability of Detection (%)		Scenario Information (dBm)	
Subtest	Mode S	ATCRBS	FRUIT Level	Power Level
1	100	100	None	-70
2	100	100	None	-73
3	100	100	None	-76
4	100	100	None	-79
5	100	100	Moderate	-70
6	100	99.98	Moderate	-73
7	100	100	Moderate	-76
8	100	99.96	Moderate	-79
9	100	99.08	Heavy	-70
10	100	99.10	Heavy	-73
11	99.96	98.22	Heavy	-76
12	99.64	96.29	Heavy	-79

The data highlights the fact that Mode S performance is stable regardless of FRUIT level tested while ATCRBS performance is degraded slightly by increasing FRUIT levels.

4.2.7 Conclusions.

All objectives for this test were verified. The Pd and Pfa objectives were met, and the Pd and Pfa operational baseline was established.

The sensor's performance was generally better with Mode S targets than with ATCRBS. Specifically, there was less degradation in the Pd due to decreasing received signal power levels or increasing FRUIT levels.

A summation of the results as they relate to each objective is shown in table 4.2.7-1.

TABLE 4.2.7-1. OBJECTIVE SUMMARY

OBJECTIVE	VERIFIED?
1. ATCRBS and Mode S Pd > 99 percent for received reply power of -76 dBm in the absence of FRUIT.	YES
2. ATCRBS and Mode S Pfa < 10^{-6}	YES
3. Establish a baseline of Pd versus RF signal levels and FRUIT levels.	YES
4. Establish a baseline of Pfa versus FRUIT levels.	YES

4.3 SURVEILLANCE BASELINE - REPORT PARAMETERS.

4.3.1 Purpose.

This test evaluated Mode S surveillance performance under typical target load and capacity situations. The following surveillance report data was collected and analyzed:

a. Beacon blip/scan ratio
b. Effective blip/scan ratio (includes radar substitution)
c. ID code validity
d. Altitude code validity
e. False targets due to splits and FRUIT
f. Mode S interrogation rate
g. Mode S reinterrogation rate

4.3.2 Test Objectives.

The objectives for this test were as follows:

a. Objective 1: To verify that the beacon blip/scan ratio for Mode S exceeds 98 percent and that the beacon blip/scan ratio for ATCRBS exceeds 97 percent.

b. Objective 2: To verify that the effective blip/scan ratio (including radar substitution) exceeds 99 percent for both Mode S and ATCRBS.

c. Objective 3: To verify that the ID code validity exceeds 97 percent for ATCRBS and 99.9 percent for Mode S.

d. Objective 4: To verify that the altitude code validity exceeds 95 percent for ATCRBS and 99.9 percent for Mode S.

e. Objective 5: To verify that false reports due to splits and FRUIT are less than 0.3 percent for ATCRBS and less than 0.1 percent for Mode S.

f. Objective 6: To verify that an ATCRBS/Mode S All-Call can be generated.

g. Objective 7: To verify that a Mode S Roll Call can be generated.

h. Objective 8: To verify that the average Mode S reinterrogation rate is less than 0.10 reinterrogations per target report.

4.3.3 Test Configuration.

Figure 4.3.3-1 depicts the configuration for this test.

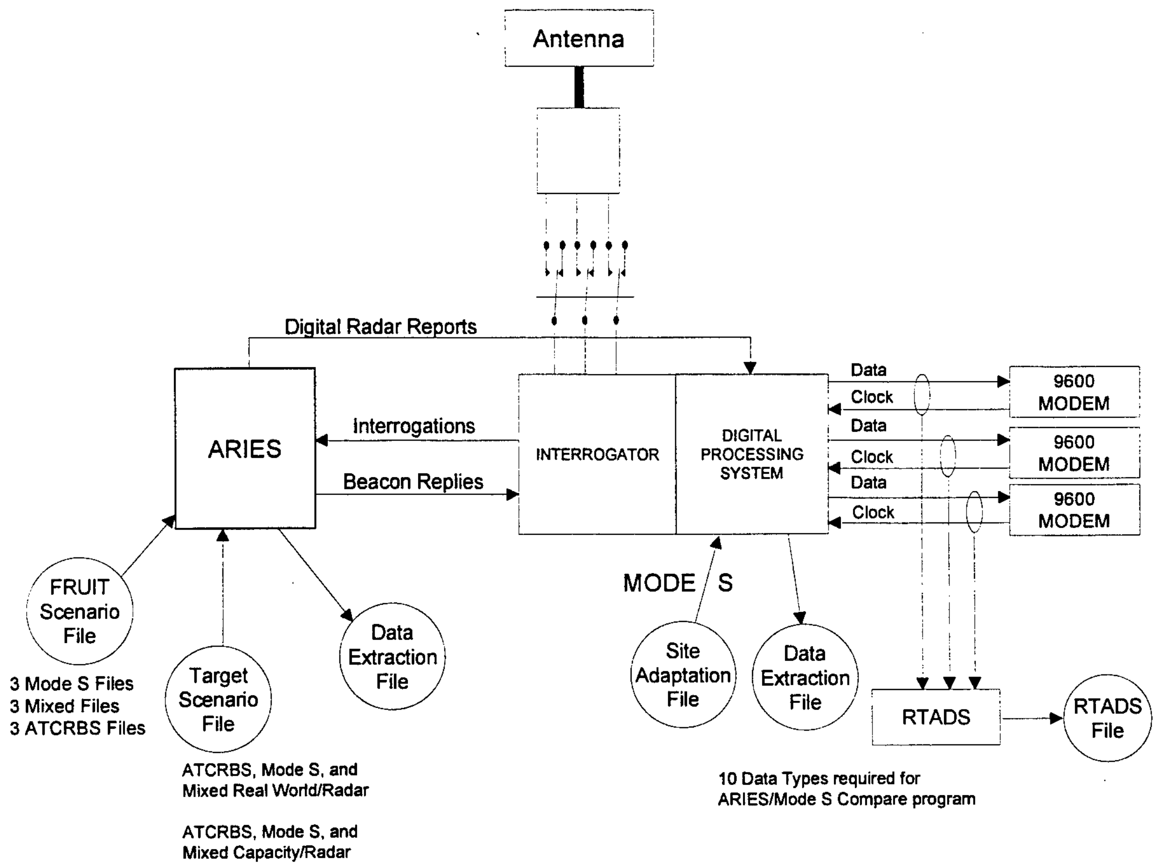


FIGURE 4.3.3-1. SURVEILLANCE BASELINE - REPORT PARAMETERS

4.3.4 Test Description.

The sensor was operating with a dummy load rather than the antenna. Eighteen subtests were executed using ARIES target scenarios and FRUIT scenarios. Two types of ARIES target scenarios were used:

a. Real world scenarios (derived from data recorded at Elwood site)
b. Capacity scenarios with a maximum of 700 targets

Both the real world and capacity scenarios were executed using only ATCRBS targets, only Mode S targets, and an equal mixture of ATCRBS and Mode S targets. Each scenario was executed using no FRUIT, moderate FRUIT (4 k/sec ATCRBS and 50/sec Mode S), or heavy FRUIT (40 k/sec ATCRBS and 200/sec Mode S) scenarios. Twenty-five percent of the FRUIT was mainbeam FRUIT.

For these tests, the sensor was loaded with the standard ARIES configuration. To enable the 80-percent radar reinforcement, it was necessary to install ARIES Radar Report cables into a Mode S communications junction box. The cables from ports J49, J50, J69, and J70 were unplugged. The ARIES cable for Channel (Ch) A was plugged into J49, and the ARIES cable for Ch B was plugged into J50.

4.3.5 Data Analysis.

The data presented was produced using Mode S Sensor, ARIES, and RTADS extraction files generated during test execution. The RBAT Filter, RBAT BFTS, RBAT SA, DR Channel Management Statistics, and DR ARIES/Mode S Compare data reduction programs were run on the data collected for each subtest.

4.3.6 Test Results.

The data as it relates to each objective is presented below.

Objective 1 of the Performance Test Procedure required that the beacon blip/scan ratio (i.e., Pd) for Mode S exceed 98 percent and that the beacon blip/scan ratio (Pd) for ATCRBS exceed 97 percent. The data for all subtests exceeded the limits.

Objective 2 of the Performance Test Procedure required that the effective beacon blip/scan ratio (Pd) (including radar substitution) exceed 99 percent for both Mode S and ATCRBS. The effective blip/scan ratios (Pd) for the Mode S, ATCRBS, and Mixed scenarios exceeded 99.49 percent in every case except one; subtest 16 was 98.7 percent. This test case was a capacity, all ATCRBS scenario in a heavy ATCRBS and Mode S FRUIT environment and some degradation of ATCRBS performance is expected. The data for Beacon Pd and Effective Pd is given in table 4.3.6-1. Note that the Mode S performance consistently exceeded the ATCRBS performance for both of these parameters. The conditions field of table 4.3.6-1 defines the scenario type, FRUIT level, and target mix.

Objective 3 of the Performance Test Procedure required that the ID code validity exceed 97 percent for ATCRBS targets and 99.9 percent for Mode S targets. The limits for ATCRBS and Mode S targets were met on all subtests. The average ID code validity for ATCRBS was 99.43 percent and the average for Mode S targets was 99.99 percent. Given these results, this objective is considered verified.

TABLE 4.3.6-1. BEACON AND EFFECTIVE Pd DATA

Subtest	Beacon Pd (%)		Effective Pd (%)		Environment
	ATCRBS	Mode S	ATCRBS	Mode S	
1	99.9	N/A	99.97	N/A	RW/NF/A
2	N/A	99.97	N/A	99.99	RW/NF/S
3	99.91	100	99.97	100	RW/NF/M
4	99.89	N/A	99.97	N/A	RW/MF/A
5	N/A	99.96	N/A	99.99	RW/MF/S
6	99.9	100	99.96	100	RW/MF/M
7	99.0	N/A	99.57	N/A	RW/HF/A
8	N/A	99.96	N/A	99.97	RW/HF/S
9	99.25	99.99	99.8	100	RW/HF/M
10	99.32	N/A	99.63	N/A	CP/NF/A
11	N/A	99.83	N/A	99.83	CP/NF/S
12	99.67	99.77	99.74	99.77	CP/NF/M
13	99.3	N/A	99.63	N/A	CP/MF/A
14	N/A	99.82	N/A	99.82	CP/MF/S
15	99.5	99.75	99.6	99.75	CP/MF/M
16	97.96	N/A	98.7	N/A	CP/HF/A
17	N/A	99.8	N/A	99.8	CP/HF/S
18	98.97	100	99.49	100	CP/HF/M
Average	99.38	99.9	99.67	99.91	
Limits	>97.0	>98.0	>99.0	>99.0	
Limits Met?	YES	YES	YES	YES	

Legend:
A = ATCRBS Targets
S = Mode S Targets
M = Mixed Targets
RW = Real World Scenario
CP = Capacity Scenario
N/A = Not Applicable
NF = No FRUIT Scenario
MF = Moderate FRUIT Scenario (4 k/sec ATCRBS, 50/sec Mode S)
HF = Heavy FRUIT Scenario (40 k/sec ATCRBS, 200/sec Mode S)

Objective 4 of the Performance Test Procedure required that the altitude code validity exceed 95 percent for ATCRBS and 99.9 percent for Mode S. All subtests exceeded the limit for Mode S targets; however, subtests 7, 9, 16, and 18 failed for ATCRBS targets, all of which were under a heavy FRUIT environment. The worst case failure (subtest 7) was 2.78 percent lower than the requirement but the average of all the subtests still exceeded the limit. Note that the sensor performed better with Mode S targets than it did with ATCRBS targets. The ID and altitude validity data are given in table 4.3.6-2.

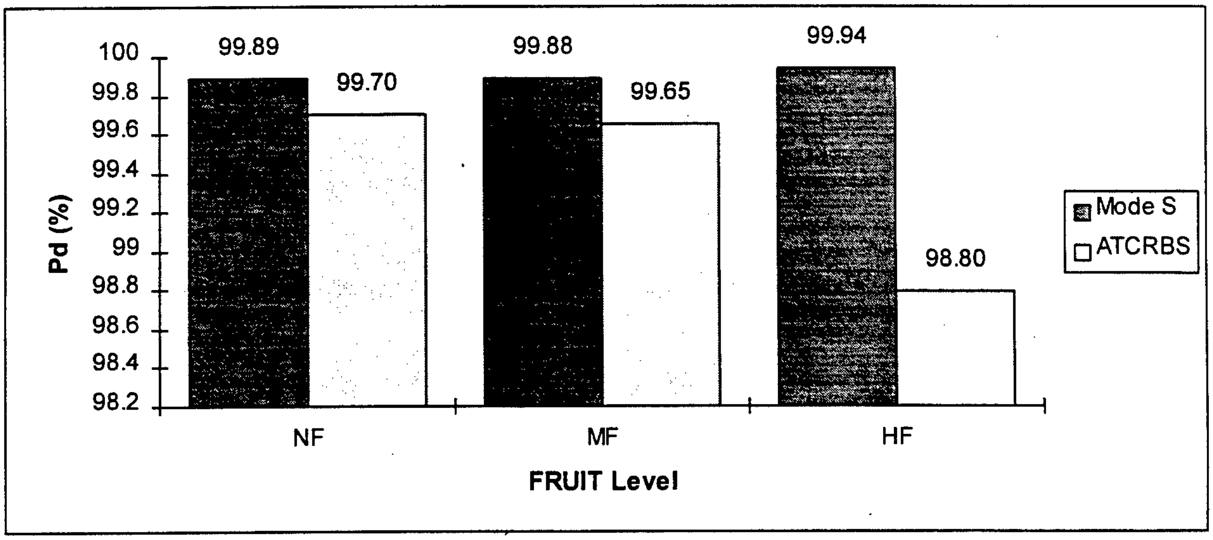
TABLE 4.3.6-2. ID CODE AND ALTITUDE CODE VALIDITY DATA

Subtest	ID Code Validity (%)		Altitude Code Validity (%)		Conditions
	ATCRBS	Mode S	ATCRBS	Mode S	
1	99.84	N/A	99.35	N/A	RW/NF/A
2	N/A	99.99	N/A	99.97	RW/NF/S
3	99.93	99.99	99.69	99.99	RW/NF/M
4	99.84	N/A	99.13	N/A	RW/MF/A
5	N/A	99.99	N/A	99.97	RW/MF/S
6	99.89	99.99	99.44	99.99	RW/MF/M
7	98.76	N/A	92.22	N/A	RW/HF/A
8	N/A	99.98	N/A	99.97	RW/HF/S
9	98.73	100	92.69	100	RW/HF/M
10	99.3	N/A	98.78	N/A	CP/NF/A
11	N/A	100	N/A	100	CP/NF/S
12	99.88	100	99.23	100	CP/NF/M
13	99.33	N/A	98.55	N/A	CP/MF/A
14	N/A	100	N/A	100	CP/MF/S
15	99.84	100	99.02	100	CP/MF/M
16	98.51	N/A	93.98	N/A	CP/HF/A
17	N/A	100	N/A	100	CP/HF/S
18	99.34	100	94.53	100	CP/HF/M
Average	99.43	99.99	97.22	99.99	N/A
Limits	>97.0	>99.9	>95.0	>99.9	N/A
Limits Met?	YES	YES	YES	YES	N/A

Legend:
A = ATCRBS Targets
S = Mode S Targets
M = Mixed Targets
RW = Real World Scenario
CP = Capacity Scenario

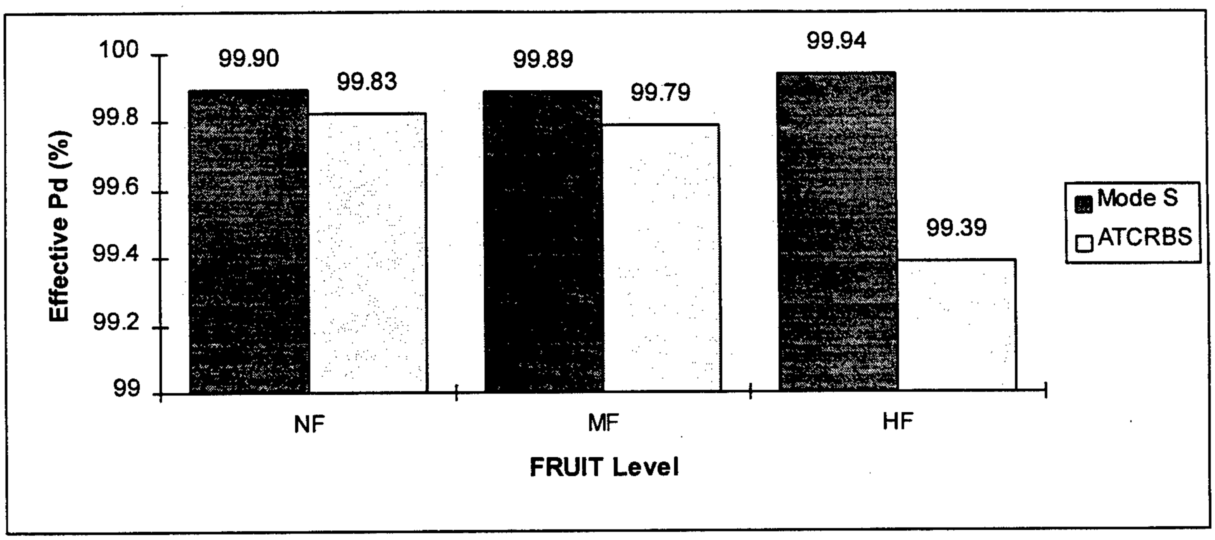
N/A = Not Applicable
NF = No FRUIT Scenario
MF = Moderate FRUIT Scenario (4 k/sec ATCRBS, 50/sec Mode S)
HF = Heavy FRUIT Scenario (40 k/sec ATCRBS, 200/sec Mode S)
* = Not Executed

Figures 4.3.6-1, 4.3.6-2, 4.3.6-3, and 4.3.6-4 present the average value of each parameter as a function of FRUIT level. Note that Mode S performance is generally superior to ATCRBS performance. In addition, Mode S performance is much less subject to degradation with increasing levels of FRUIT.



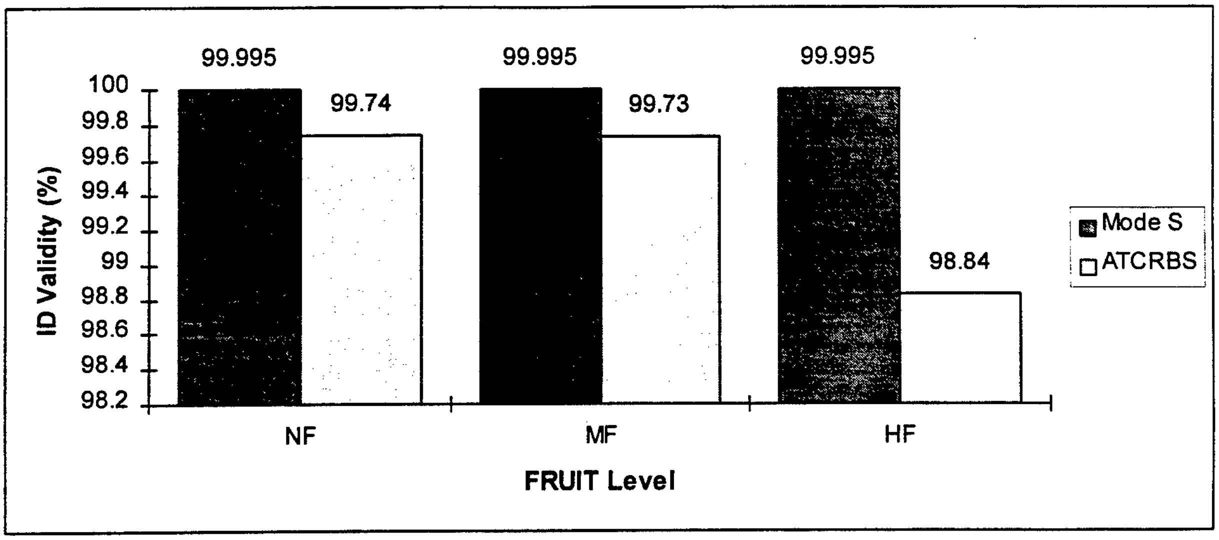
Legend:
NF = No FRUIT
MF = Moderate FRUIT (4 k/sec ATCRBS, 50/sec Mode S)
HF = Heavy FRUIT (40 k/sec ATCRBS, 200/sec Mode S)

FIGURE 4.3.6-1. BEACON PROBABILITY OF DETECTION DATA



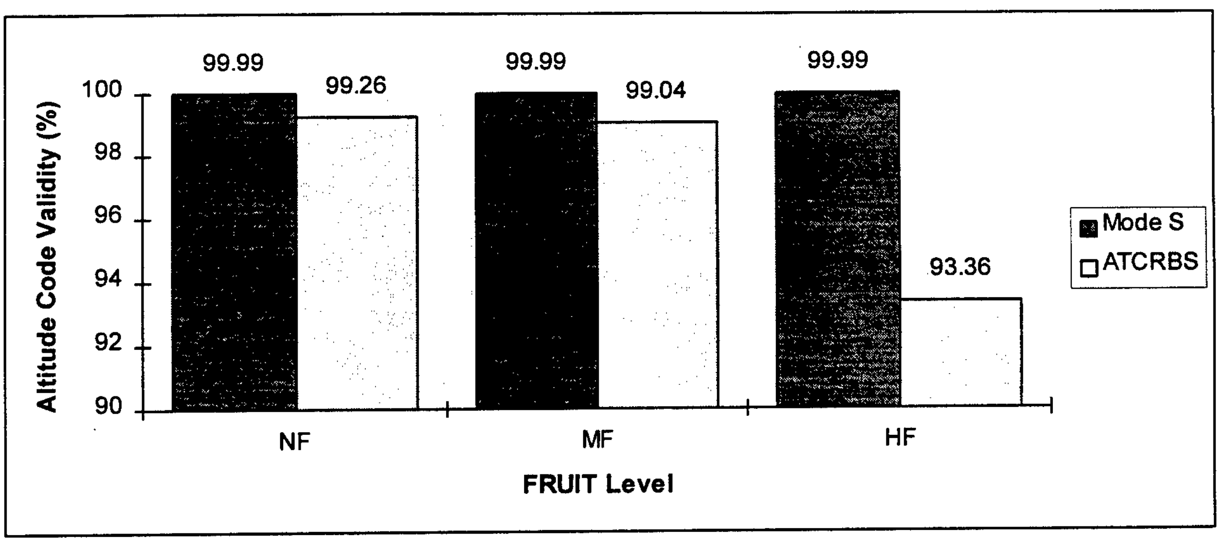
Legend:
NF = No FRUIT
MF = Moderate FRUIT (4 k/sec ATCRBS, 50/sec Mode S)
HF = Heavy FRUIT (40 k/sec ATCRBS, 200/sec Mode S)

FIGURE 4.3.6-2. EFFECTIVE PROBABILITY OF DETECTION DATA



Legend:
NF = No FRUIT
MF = Moderate FRUIT (4 k/sec ATCRBS, 50/sec Mode S)
HF = Heavy FRUIT (40 k/sec ATCRBS, 200/sec Mode S)

FIGURE 4.3.6-3. ID CODE VALIDITY DATA



Legend:
NF = No FRUIT
MF = Moderate FRUIT (4 k/sec ATCRBS, 50/sec Mode S)
HF = Heavy FRUIT (40 k/sec ATCRBS, 200/sec Mode S)

FIGURE 4.3.6-4. ALTITUDE CODE VALIDITY DATA

Objective 5 of the Performance Test Procedure required that false reports due to splits and FRUIT were less than 0.3 percent for ATCRBS and less than 0.1 percent for Mode S. All of the subtests easily passed this requirement, both on ATCRBS and Mode S targets. Table 4.3.6-3 summarizes the False Targets due to Splits and FRUIT data for these tests.

TABLE 4.3.6-3. FALSE TARGETS DUE TO SPLITS AND FRUIT

Subtest	Splits (%)		Conditions
	ATCRBS	Mode S	
1	0.0	N/A	RW/NF/A
2	N/A	0.0	RW/NF/S
3	0.0	0.0	RW/NF/M
4	0.0	N/A	RW/MF/A
5	N/A	0.0	RW/MF/S
6	0.01	0.0	RW/MF/M
7	.02	N/A	RW/HF/A
8	N/A	0.0	RW/HF/S
9	0.01	0.0	RW/HF/M
10	0.0	N/A	CP/NF/A
11	N/A	0.0	CP/NF/S
12	0.0	0.0	CP/NF/M
13	0.0	N/A	CP/MF/A
14	N/A	0.0	CP/MF/S
15	0.0	0.0	CP/MF/M
16	0.0	N/A	CP/HF/A
17	N/A	0.0	CP/HF/S
18	0.01	0.0	CP/HF/M
Average	0.0028	0.0	N/A
Limits	<0.3	<0.1	N/A
Limits Met?	YES	YES	N/A

Legend:
A = ATCRBS Targets
S = Mode S Targets
M = Mixed Targets
RW = Real World Scenario
CP = Capacity Scenario
N/A = Not Applicable
NF = No FRUIT Scenario
MF = Moderate FRUIT Scenario (4 k/sec ATCRBS, 50/sec Mode S)
HF = Heavy FRUIT Scenario (40 k/sec ATCRBS, 200/sec Mode S)
* = Not Executed

Objective 6 of the Performance Test Procedure required verification that ATCRBS and Mode S All-Calls were generated. The fact that all ATCRBS and Mode S subtests using capacity scenarios executed successfully (except for some of the reinterrogation rates), according to the Performance Test Procedure, verifies that multiple ATCRBS and Mode S All-Calls were successfully generated.

Objective 7 of the Performance Test Procedure required verification that Mode S Roll Calls were generated. The fact that all Mode S and Mixed subtests using capacity scenarios executed

successfully (except for some of the reinterrogation rates) along with random sampling of extracted interrogation data verifies that multiple Mode S Roll-Calls were successfully generated.

Objective 8 of the Performance Test Procedure required that the average Mode S reinterrogation rate was less than 0.10 reinterrogations per target report. This objective was not successfully validated at all ranges. The reinterrogation rate for each target was dependent on its range and directly related to the surveillance procedure algorithm that predicts earliest likely azimuth. Targets close to the sensor typically had a higher reinterrogation rate than those further away due to the greater azimuth uncertainty incurred with a short range, high velocity target. The data reduction tool Channel Management Statistics, filtered on range, was used to determine how reinterrogation rate changes as a function of range. The greatest variations in reinterrogation rate were observed in the range interval of 0 to 10 nmi. For this reason, the analysis was done by dividing the coverage map into six range bands. The ranges included in each band are:

a. $0 \leq \text{range} \leq 10$
b. $10 \leq \text{range} \leq 25$
c. $25 \leq \text{range} \leq 50$
d. $50 \leq \text{range} \leq 100$
e. $100 \leq \text{range} \leq 200$
f. $200 \leq \text{range} \leq 250$

The Channel Management Statistics program was executed once for every range band of each subtest.

The results of the analysis are given in table 4.3.6-4. This table shows how the reinterrogation rate varies with range during these tests. Also, note in figure 4.3.6-5 that the reinterrogation rate for real world and capacity scenarios both drop off significantly after 10 nmi, and remain relatively constant out to 250 nmi. Figure 4.3.6-6 illustrates the effects of FRUIT on the reinterrogation rate. As expected, the rate increased proportionally as a function of FRUIT rate.

TABLE 4.3.6-4. REINTERROGATION RATE VERSUS RANGE (nmi)

Reinterrogation Rate versus Range (nmi)							
Subtest	0≤R≤10	10≤R≤25	25≤R≤50	50≤R≤100	100≤R≤200	200≤R≤250	Scenario Type
2	0.15	0.02	0	0	0	0	RW/NF/S
3	0.18	0	0	0	0	0	RW/NF/M
5	0.13	0.02	0.01	0	0	0	RW/MF/S
6	0.26	0.01	0.01	0.01	0.02	0.03	RW/MF/M
8	0.13	0.03	0.01	0.02	0.01	0.02	RW/HF/S
9	0.41	0.18	0.16	0.2	0.25	0.29	RW/HF/M
11	0.76	0.13	0.07	0.06	0.05	0.05	CP/NF/S
12	0.77	0.12	0.08	0.06	0.05	0.06	CP/NF/M
14	0.76	0.13	0.08	0.06	0.06	0.06	CP/MF/S
15	0.77	0.13	0.08	0.06	0.06	0.05	CP/MF/M
17	0.76	0.13	0.08	0.07	0.06	0.06	CP/HF/S
18	0.77	0.15	0.11	0.11	0.14	0.18	CP/HF/M
RW Average	0.21	0.04	0.03	0.04	0.05	0.06	RW
CP Average	0.77	0.13	0.08	0.07	0.07	0.08	CP
Overall Average	0.49	0.09	0.06	0.06	0.06	0.07	N/A
Limit	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	N/A
Limit Met?	NO	YES	YES	YES	YES	YES	N/A

Legend:
A = ATCRBS Targets
S = Mode S Targets
M = Mixed Targets
RW = Real World Scenario
CP = Capacity Scenario

N/A = Not Applicable
NF = No FRUIT Scenario
MF = Moderate FRUIT Scenario (4 k/sec ATCRBS, 50/sec Mode S)
HF = Heavy FRUIT Scenario (40 k/sec ATCRBS, 200/sec Mode S)
* = Not Executed

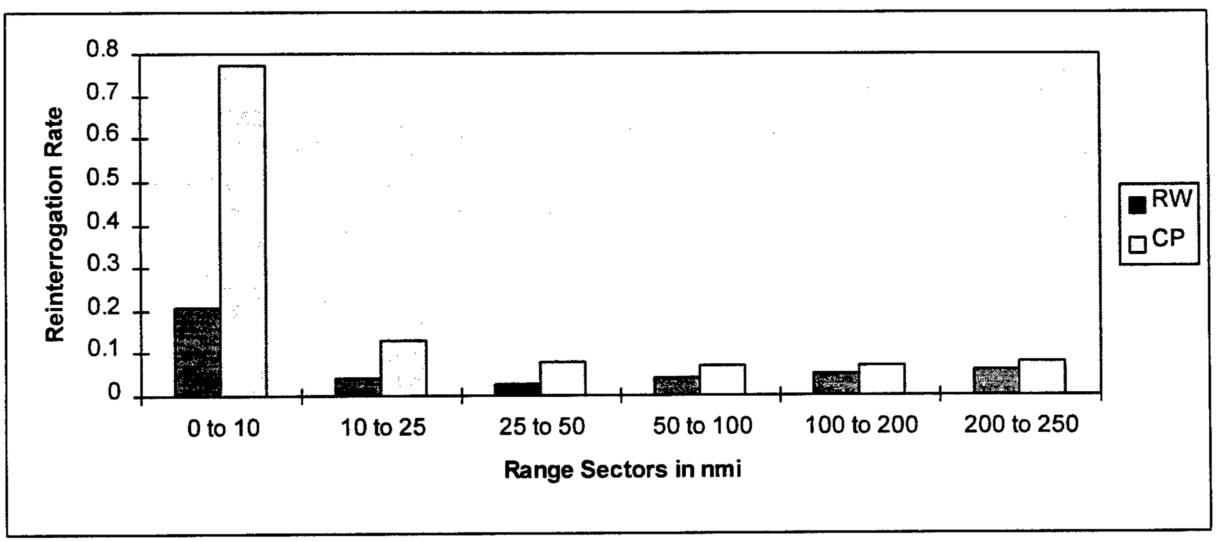


FIGURE 4.3.6-5. REINTERROGATION RATE VERSUS SCENARIO TYPE

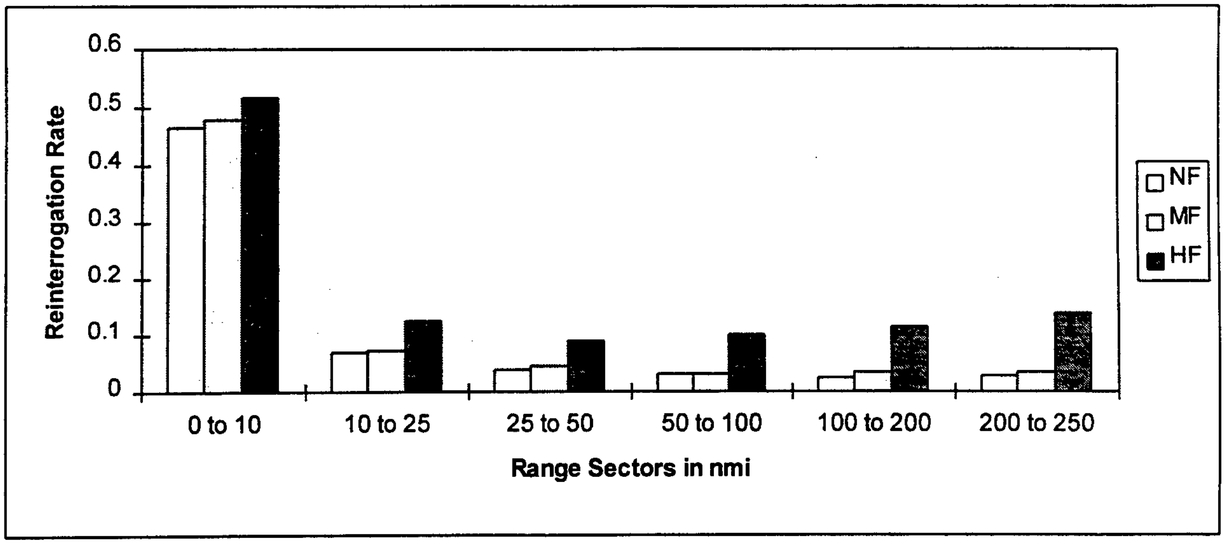


FIGURE 4.3.6-6. REINTERROGATION RATE VERSUS FRUIT LEVEL

4.3.7 Conclusions.

All the objectives for surveillance performance as measured using the ARIES simulation environment were met except for reinterrogation rate. The reinterrogation rate (objective 8) limit of less than 0.10 was not met for 0 to 10 nmi range. The overall average is just under 0.14, but the 0 to 10 nmi rate has a significant bias to this rate. The overall average for the 10 to 250 nmi area is 0.068.

Through the optimization of the system's SAPs, the reinterrogation rates have been drastically reduced, especially in comparison to the terminal OT&E results. The SAPs were changed in the area where the system determines when to schedule the earliest roll-call interrogation for a given target. Assumptions were made, relative to the enroute environment, in determining the prediction window in the tracking algorithm. One such characterization is that targets generally are not performing high-G maneuvers in the enroute airspace. Further improvement would require a modification to the Mode S specification defined algorithm. Realistically, the elevated reinterrogation rates within 10 nmi should have minimal impact within the enroute environment.

The objectives for this test and whether or not they have been verified by the testing to date is summarized in table 4.3.7-1.

TABLE 4.3.7-1. OBJECTIVE SUMMARY

OBJECTIVE	VERIFIED?
1. Mode S blip/scan >98 percent, ATCRBS blip/scan >97 percent	YES
2. Effective blip/scan >99 percent for Mode S and ATCRBS	YES
3. Mode S ID code validity >99.9 percent, ATCRBS ID code validity >97 percent	YES
4. Mode S altitude code validity >99.9 percent, ATCRBS altitude code validity >95 percent	YES
5. False reports due to splits and FRUIT <0.1 percent for Mode S, <0.3 percent for ATCRBS	YES
6. A Mode S/ATCRBS All-Call can be generated	YES
7. A Mode S Roll-Call can be generated	YES
8. Average Mode S reinterrogation rate <0.10	NO

4.4 SURVEILLANCE BASELINE - CONFLICT SITUATIONS.

4.4.1 Purpose.

These tests provided statistics to evaluate Mode S sensor performance relative to track swaps and garble when interrogating simulated ATCRBS and Mode S targets. The tracking performance was primarily concerned with the sensor's ability to maintain correct tracks on simulated targets whose paths come into close proximity to one another. The test was also concerned with examining garble reduction due to the Mode S interrogation. The ARIES provided the FRUIT environments and simulated target scenarios to generate well-defined target crossing and conflict patterns.

4.4.2 Test Objectives.

The objectives for this test were as follows:

a. Objective 1: To verify that ATCRBS track swaps are less than 1 percent.

b. Objective 2: To establish a baseline of ATCRBS track swaps data.

c. Objective 3: To verify that Mode S reduces garble by use of Mode S aircraft interrogation ability.

4.4.3 Test Configuration.

Figure 4.4.3-1 depicts the configuration for this test.

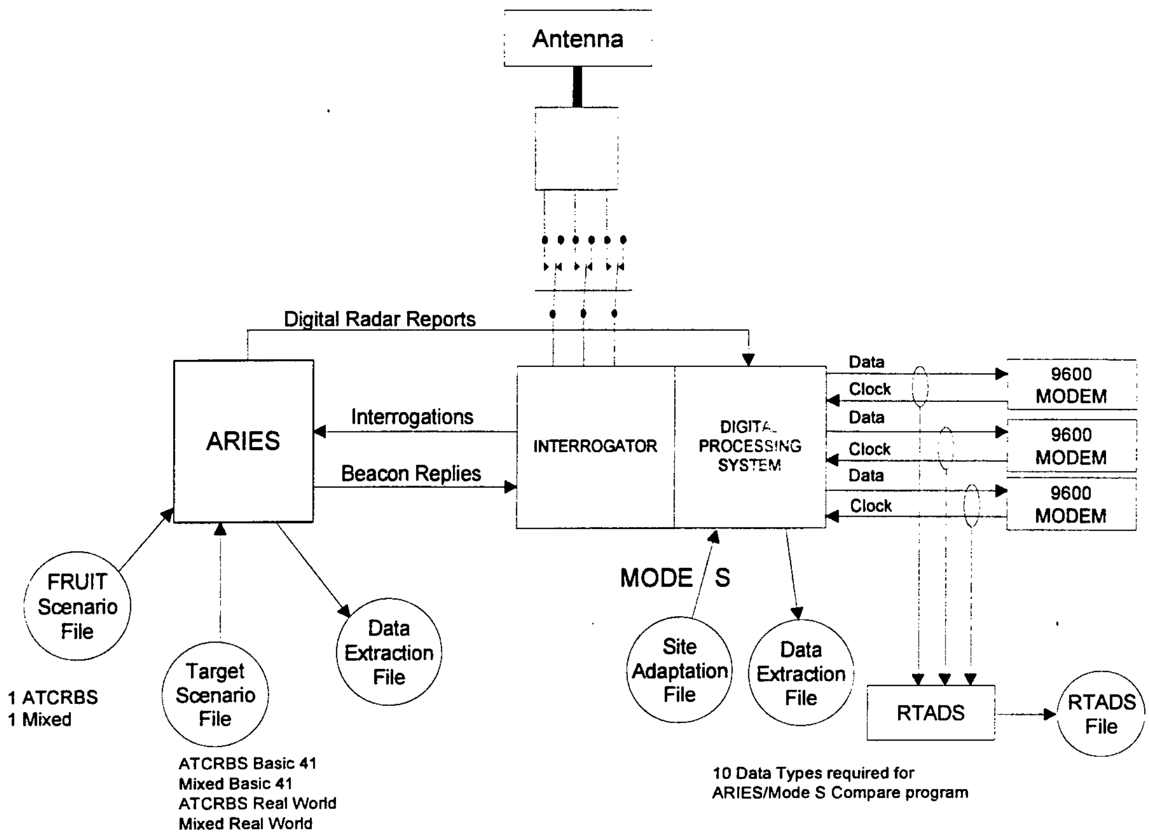


FIGURE 4.4.3-1. SURVEILLANCE BASELINE - CONFLICT SITUATIONS

4.4.4 Test Description.

The Basic 41 and Real World scenarios were used for analysis in this test. The Basic 41 scenarios simulate various stresses and conflict situations. The Real World scenarios are based on data extractions collected at the Elwood Radar Site in New Jersey.

Subtest 1 used the ATCRBS version of the Basic 41 scenario. Subtest 3 used the Mixed (ATCRBS and Mode S) version of Basic 41. The Basic 41 scenarios feature 41 aircraft with flight paths that present test cases that stress surveillance functions. See appendix D for a description of the Basic 41 target scenario. By keeping the aircraft closely spaced in range, azimuth, and altitude for long periods of time, these scenarios provide a stress situation with regard to maintaining tracks correctly. These scenarios simulate 13 conflict situations that the test is designed to evaluate.

Subtests 4 and 6 are the ATCRBS and Mixed versions of the Real World scenarios from test 3. The Real World scenarios are similar to the Basic 41 scenarios in that they provide the conflict situations needed to test the sensor. However, the Real World scenarios have many more targets and conflicts than the Basic 41 scenarios.

The sensor was configured for ARIES operation for all subtests. An RTADS, ARIES, and Mode S extraction file was collected for each subtest. All of the subtests were executed using the appropriate moderate FRUIT scenario.

4.4.5 Data Analysis.

Reduction and analysis were performed on the extraction files using the RBAT and DR family of programs. The RBAT program Conflict Analysis was run on each subtest using the RTADS extraction file. This program was used to identify the conflicts to be analyzed for each subtest. For the purposes of this test, a conflict was defined as two or more targets within 2 nmi and 4° of each other. These are the limits given in the test procedure.

The RBAT SA and Surveillance File Analysis programs were run on the Mode S extraction file for each subtest. SA was used to provide parameters such as Beacon Pd, ID code reliability and validity, and altitude reliability and validity for the targets. Surveillance File Analysis was used to obtain scan-by-scan information on the target's ID and position in space. This information was needed to determine whether a track swap had occurred. To help analyze complex conflicts, the Surveillance File Analysis program was used with the time, slant range, and azimuth limits of each particular conflict. Doing this limited the targets shown in the program's output to the targets involved in the conflict, greatly reducing the number of targets to be analyzed.

The DR ARIES/Mode S Compare program was run once for each subtest using the appropriate ARIES and Mode S extraction files. This program provided much of the same information as the SA program, but ARIES/Mode S Compare provides that information at the Reply, Report, and Disseminated levels. As garbled replies are not used in reports, the differences between data at the various levels give a measure of garble.

4.4.6 Test Results.

There were three Test Objectives to be verified.

Objective 1 states that ATCRBS track swaps be less than 1 percent. On average, this was the case. The average ATCRBS track swap percentage was 0.0 percent, i.e., no track swaps could be induced.

Objective 2 states that a baseline of ATCRBS track swap data will be established. This was done.

Objective 3 states that the Mode S must reduce garble by use of Mode S aircraft interrogation ability. There were no track swaps involving Mode S targets, and garble problems were less numerous in subtests involving Mode S targets.

The results of each subtest are presented individually.

a. Subtest 1: ATCRBS, Basic 41 - The DR SA program identified 45 tracks with no swaps, therefore the track swap percentage of 0 percent. The Basic 41 scenario used for this subtest presents the sensor with multiple stress situations well above the percentage in normal

live traffic environments. The test ran better than in the terminal environment, which had one swap during that test period.

b. Subtest 3: Mixed (ATCRBS and Mode S), Basic 41 - There were no significant problems to report with this subtest. There were no track swaps, and no tracks that coasted and were dropped during a conflict.

c. Subtest 4: ATCRBS, Real World - With a total of 336 tracks in the scenario, there were no track swaps. The track swap percentage is 0 percent, which is under the 1.0-percent track swap limit, indicating that Objective 1 was met for this subtest.

d. Subtest 6: Mixed (ATCRBS and Mode S), Real World - There were no track swaps in this subtest. With 336 tracks this indicates a track swap percentage of 0 percent. This is under the 1.0-percent limit of Objective 1.

4.4.7 Conclusions.

All of the subtests passed the 1.0-percent track swap limit of Objective 1. The total track swap percentage for all the subtests was 0 percent. Since this is below the limit, Objective 1 is considered verified. The track swap data percentages for these tests are presented in table 4.4.7-1.

TABLE 4.4.7-1. TRACK SWAP PERCENTAGES

SUBTEST	1	3	4	6	TOTAL
NO. TRACKS	45	45	336	336	762
NO. SWAPS	0	0	0	0	0
PERCENTAGE	0.0%	0.0%	0.0%	0.0%	0.0%
LIMIT MET?	YES	YES	YES	YES	YES

The data in this table can be used to establish a baseline for track swap percentage, satisfying Objective 2.

All of the objectives defined for this procedure have been met, and there are no deficiencies to report. A summary of the objectives and their verification is given in table 4.4.7-2.

TABLE 4.4.7-2. OBJECTIVE SUMMARY

OBJECTIVE	VERIFIED?
1. ATCRBS track swaps <1 percent.	YES
2. Establish a baseline of ATCRBS track swap data.	YES
3. Verify that Mode S reduces garble by using the Mode S aircraft interrogation ability.	YES

4.5 DATA LINK BASELINE.

4.5.1 Purpose.

This test measured the ability of the Mode S sensor to correctly transmit uplink messages and to correctly process downlink messages. Baseline data included uplink message delay, downlink message delay, uplink and downlink message storage capacity, and message completion classified by priority. The test was executed using the ARIES and the Communications Interface Driver (CID) to simulate capacity communications scenarios. Three FRUIT levels were used; no FRUIT, moderate FRUIT, and heavy FRUIT.

4.5.2 Test Objectives.

The objectives for this test were as follows:

a. Objective 1: To verify that the sensor does not delay uplink messages more than 1/16 of a scan.

b. Objective 2: To verify that the sensor does not delay downlink messages more than 1/16 of a scan.

c. Objective 3: To verify that the sensor prioritizes message transmissions per the Mode S specification.

d. Objective 4: To verify that the sensor can receive or output data link messages for 700 Mode S-equipped aircraft per scan.

e. Objective 5: To verify that the sensor can receive or output data link messages for the following per scan target capacity scenarios:

1. A mixture of 700 Mode S and ATCRBS beacon targets,
2. 1000 primary radar target reports, and
3. Nonuniform beacon target distribution of:

(a) 250 targets within a 90° quadrant,
(b) 50 targets within an 11.25° sector for up to four consecutive sectors, and
(c) 32 targets within a 2.4° wedge.

f. Objective 6: To verify that the sensor efficiently utilizes the data channel under the conditions listed in the peaking scenario description.

g. Objective 7: To verify that the sensor can store up to 4800 uplink messages.

h. Objective 8: To verify that the sensor can store up to 1100 downlink messages.

4.5.3 Test Configuration.

Figure 4.5.3-1 depicts the configuration for this test.

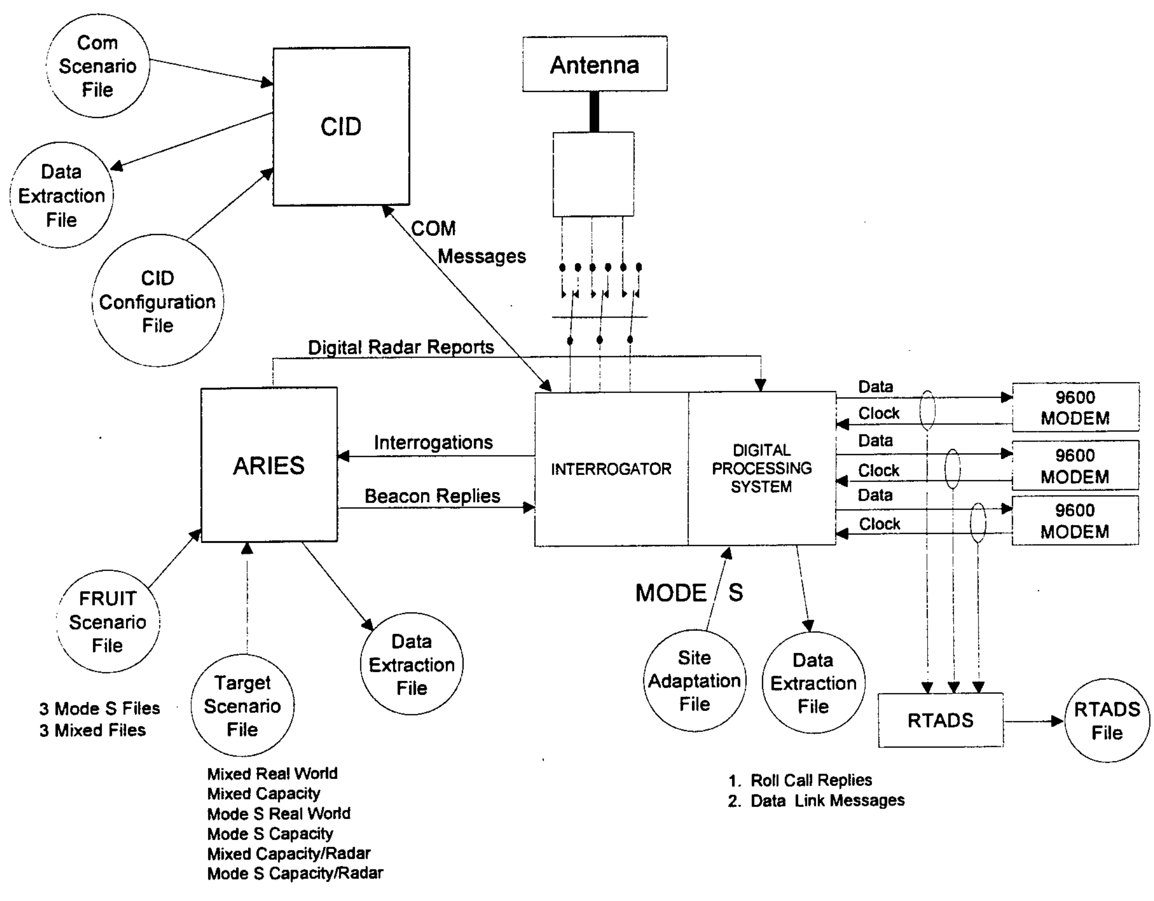


FIGURE 4.5.3-1. DATA LINK BASELINE

4.5.4 Test Description.

For this test the Mode S sensor was operated using the dummy load. The ARIES and CID scenarios were used to generate simulated targets and their associated communications messages. Three FRUIT scenarios were used; no FRUIT, moderate FRUIT, and heavy FRUIT. Data extractions were made from the output of the ARIES, CID, Mode S sensor, and RTADS.

The test used capacity ARIES and CID scenarios. For each of the scenarios there is an ATCRBS version, a Mode S version, and a mixed version (ATCRBS and Mode S). The

capacity scenarios were designed to test the Mode S sensor's ability to process 700 targets per scan. Again, separate data files were developed for Mode S only and mixed ATCRBS/Mode S scenarios.

4.5.5 Data Analysis.

Reduction and analysis were performed on the extractions identified above using the DR "Data Link Statistics" program and the RBAT "Surveillance Analysis" program. These programs were run once for each subtest using the appropriate extraction file.

4.5.6 Test Results.

There were eight Test Objectives to be verified.

Objective 1 states that the sensor must not delay uplink messages more than 1/16 of a scan. The objective was verified during the Sensor Design Qualification #5 (SDQ5) Formal Acceptance Test. Due to the required level of instrumentation needed to verify this objective and the very low risk associated with the utilization of previous data, previous tests are being referenced. The sensor software level tested was Release 16.2, consisting of the Interrogator Software Version 19 and the Data Processing Subsystem (DPS) Software version Mode S 1.1. The SDQ5 Test Report documents the verification of these objectives (TM-PA-0018/624/00, dated June 8, 1992, CLIN 16E3e).

Objective 2 states that the sensor must not delay downlink messages more than 1/16 of a scan. The objective was verified during the SDQ5 Formal Acceptance Test. As identified in objective 1, retesting was not considered to be necessary. The SDQ5 Test Report documents the verification of these objectives (TM-PA-0018/624/00, dated June 8, 1992, CLIN 16E3e).

Objective 3 states that the sensor prioritizes message transmissions per the Mode S specification. This objective was verified during the Real Time Formal Qualification Test 2 (FQT2) (Data Link). The software under test was at the cset of build 1.1.13.7. The Software Test Report, Real Time FQT2 Data Link, discusses the verification of this objective (TM-PA-0018/756/01, dated July 24, 1991, CLIN 16f7-3H).

Objective 4 states that the sensor must be capable of receiving or transmitting data link messages for 700 Mode S-equipped aircraft per scan. This objective was tested and met.

Objective 5 states that the sensor must be capable of receiving or transmitting data link messages for the following target capacity scenarios:

a. Any mixture of 700 Mode S and ATCRBS beacon targets,
b. 1000 primary radar target reports, and
c. Nonuniform beacon target distribution of:

    1. 250 targets within a 90° quadrant,
    2. 100 targets within an 11.25° sector for up to four consecutive sectors, and
    3. 32 targets within a 2.4° wedge.

This objective was met.

Objective 6 states that the sensor must efficiently utilize the data channel under the conditions listed in the peaking scenario described in the Test Verification Requirements Traceability Matrix (TVRTM), table 3.2.1.1.6.2.13-1. Efficient usage of the data channel resulted in a high delivery rate of messages. This objective was verified.

Objective 7 states that the sensor must store up to 4800 uplink messages. The objective was verified during the SDQ5 Formal Acceptance Test. The SDQ5 Test Report documents the verification of these objectives (TM-PA-0018/624/00, dated June 8, 1992, CLIN 16E3e).

Objective 8 states that the sensor can store up to 1100 downlink messages. This objective was verified during the SDQ5 Formal Acceptance Test. The SDQ5 Test Report documents the verification of these objectives (TM-PA-0018/624/00, dated June 8, 1992, CLIN 16E3e).

The data accumulated indicates that the sensor is performing up to specifications. For the eight subtests executed, an average of 99.1 percent of the messages was delivered. An average of 0.2 percent expired; 0.7 percent were rejected; and 0.0 percent were delayed.

Table 4.5.6-1 illustrates the test results when the Mode S capacity scenario was executed. An average of 99.1 percent of the messages was delivered.

TABLE 4.5.6-1. MODE S CAPACITY SCENARIO RESULTS

Subtest	Delivered (%)	Rejected (%)	Delayed (%)	Expired (%)	FRUIT Level
10	99.1	0.7	0.0	0.2	None
11	99.1	0.7	0.0	0.2	MF
12	99.1	0.7	0.0	0.2	HF
Average	99.1	0.7	0.0	0.2	N/A

Legend:
MF = Moderate FRUIT scenario (4 k/sec ATCRBS, 50/sec Mode S)
HF = Heavy FRUIT scenario (40 k/sec ATCRBS, 200/sec Mode S)
N/A = Not Applicable

Table 4.5.6-2 summarizes the data for the mixed capacity scenarios.

TABLE 4.5.6-2. MIXED CAPACITY SCENARIO RESULTS

Subtest	Delivered (%)	Rejected (%)	Delayed (%)	Expired (%)	FRUIT Level
4	99.1	0.8	0.0	0.1	None
5	99.4	0.5	0.0	0.1	MF
6	98.7	1.1	0.0	0.3	HF
Average	99.1	0.8	0.0	0.2	N/A

Legend:
MF = Moderate FRUIT scenario (4 k/sec ATCRBS, 50/sec Mode S)
HF = Heavy FRUIT scenario (40 k/sec ATCRBS, 200/sec Mode S)
N/A = Not Applicable

The radar-reinforced data (subtests 13 and 14) is consistent with the other subtests executed. The percentage of messages delivered is an acceptable 99.3 percent. The percentage of expired messages is also within acceptable limits and consistent with other data. This data is detailed in table 4.5.6-3.

TABLE 4.5.6-3. RADAR REINFORCED, CAPACITY SCENARIO RESULTS

Subtest	Delivered (%)	Rejected (%)	Delayed (%)	Expired (%)	FRUIT Level
13	99.5	0.4	0.0	0.1	MF
14	99.1	0.7	0.0	0.5	MF
Average	99.3	0.55	0.0	0.15	N/A

Legend:
MF = Moderate FRUIT scenario (4 k/sec ATCRBS, 50/sec Mode S)
N/A = Not Applicable

This test also verified that data link activity did not affect surveillance performance by the Mode S. Table 4.5.6-4 illustrates Mode S surveillance performance while the data link is in use.

TABLE 4.5.6-4. SURVEILLANCE PERFORMANCE

Subtest	Beacon Pd (%)		ID Reliability (%)		ID Validity (%)		Altitude Reliability (%)		Altitude Validity (%)	
	ATCRBS	Mode S	ATCRBS	Mode S	ATCRBS	Mode S	ATCRBS	Mode S	ATCRBS	Mode S
4	99.58	99.81	99.72	99.99	99.86	100	99.51	100	99.52	100
5	99.53	99.7	99.67	99.99	99.8	100	99.35	100	99.37	100
6	97.61	98.29	98.99	99.99	99.41	100	99.43	99.99	95.44	100
10	N/A	99.99	N/A	100	N/A	100	N/A	100	N/A	100
11	N/A	95.1	N/A	100	N/A	100	N/A	100	N/A	100
12	N/A	99.98	N/A	99.99	N/A	99.99	N/A	100	N/A	100
13	99.79	99.98	99.76	100	99.88	100	99.43	100	99.46	100
14	N/A	99.99	N/A	100	N/A	100	N/A	100	N/A	100
Average	99.13	99.11	99.54	100	99.74	100	99.43	100	99.45	100

Table 4.5.6-5 and figure 4.5.6-1 compare the surveillance data observed in this test with the data from test 3 (Surveillance Baseline-Report Parameters) and test 6 (Sensor Coverage). Test 3 used simulated targets generated by ARIES, while test 6 used live targets. Neither test 3 nor test 6 used the data link. Consideration of the data in table 4.5.6-5 and figure 4.5.6-1 shows that the sensor's performance with regard to surveillance parameters was not significantly degraded by using the data link.

TABLE 4.5.6-5. TEST 5 VERSUS TEST 3 AND TEST 6

	BEACON Pd (%)		ID VALIDITY (%)		ALTITUDE VALIDITY (%)	
	MODE S	ATCRBS	MODE S	ATCRBS	MODE S	ATCRBS
TEST 5	99.22	99.69	99.99	99.84	100	99.45
TEST 3	99.9	99.38	99.99	99.43	99.99	97.22
TEST 6	99.55	98.55	99.97	99.85	99.97	98.65
TEST 3 LIMIT	>99.0	>97.0	>99.0	>97.0	>99.9	>95.00
LIMIT MET?	YES	YES	YES	YES	YES	YES

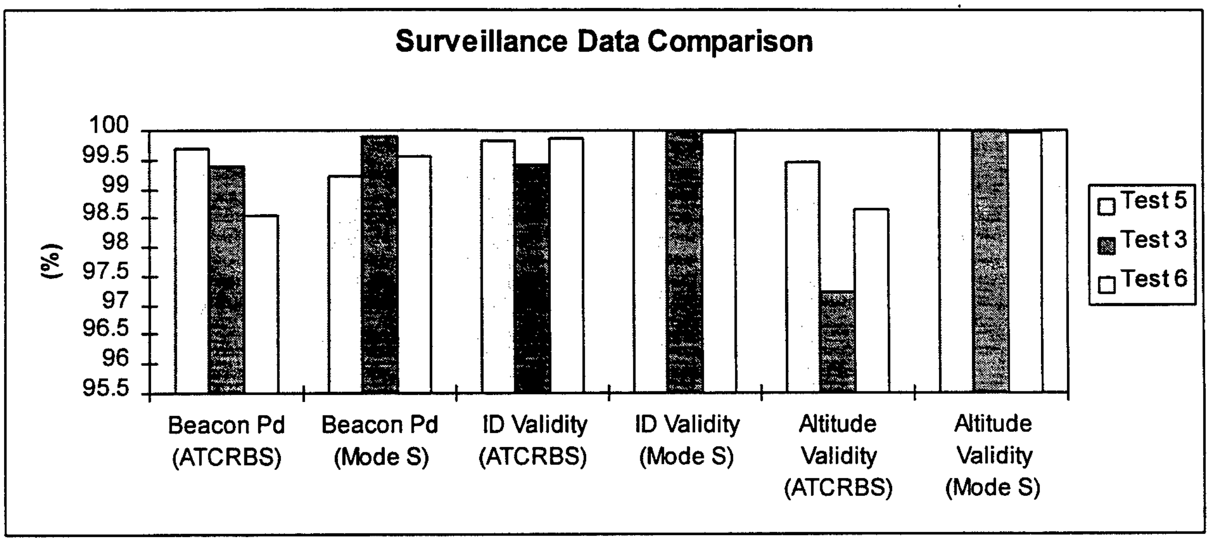


FIGURE 4.5.6-1. TEST 5 VERSUS TEST 3 AND TEST 6

4.5.7 Conclusions.

All of the objectives for this test were met. Some of the objectives were verified during this test, others were met during SDQ5 Formal Acceptance Test. The objectives for this test and their verification to date are summarized in table 4.5.7-1.

TABLE 4.5.7-1. OBJECTIVE SUMMARY

OBJECTIVE	VERIFIED?
1. Uplink message delay <1/16 of a scan	YES
2. Downlink message delay <1/16 of a scan	YES
3. Messages prioritized as per Mode S specification	YES
4. Sensor can receive or output 700 messages per scan	YES
5. Sensor can receive or output messages using capacity target distributions	YES
6. Sensor efficiently utilizes the data channel under peaking conditions	YES
7. Verify that the sensor can store up to 4800 uplink messages	YES
8. Verify that the sensor can store up to 1100 downlink messages	YES

4.6 MODE S SENSOR COVERAGE AND SURVEILLANCE PERFORMANCE USING OPEN ARRAY ANTENNA.

4.6.1 Purpose.

This test measured the coverage volume of the sensor as well as the following surveillance parameters; (1) blip/scan, (2) ID code validity, (3) altitude code validity, and (4) false targets due to splits and FRUIT. The values of the surveillance parameters listed above were recorded for live targets. The results of the live world testing were compared with the simulated target data gathered in test 3 (Surveillance Baseline-Report Parameters).

4.6.2 Test Objectives.

The objectives for this test were as follows;

a. Objective 1: To compare the beacon blip/scan ratio for ATCRBS and Mode S targets against the baseline data of test 3 (Surveillance Baseline-Report Parameters).

b. Objective 2: To compare the ID code validity for ATCRBS and Mode S targets against the baseline data of test 3 (Surveillance Baseline-Report Parameters).

c. Objective 3: To compare the altitude code validity for ATCRBS and Mode S targets against the baseline data of test 3 (Surveillance Baseline-Report Parameters).

d. Objective 4: To compare the false reports due to splits for ATCRBS and Mode S targets against the baseline data of test 3 (Surveillance Baseline-Report Parameters).

e. Objective 5: To verify that the slant range coverage for the terminal sensor is 0.5 nmi to 55 nmi.

f. Objective 6: To verify that the slant range coverage for the enroute sensor is 0.5 nmi to 255 nmi.

g. Objective 7: To verify that the azimuth coverage is 360°.

h. Objective 8: To verify that the altitude coverage shall be to 100,00 feet.

i. Objective 9: To verify that the elevation coverage is 0.5° to 45°.

j. Objective 10: To verify that the sensor detects all transponder equipped aircraft at a rate identical with that of the associated primary radar.

k. Objective 11: To verify that the Mode S terminal sensor updates surveillance reports on all targets within the detection envelope every antenna scan.

l. Objective 12: To verify that the Mode S enroute sensor updates surveillance reports on all targets within the detection envelope twice per antenna scan when operating with a back-to-back beacon antenna.

m. Objective 13: To verify that the Mode S enroute sensor detects all transponder equipped aircraft within the detection envelope at a rate of 12 seconds, +1.33 or -1.09 seconds.

Objectives 5 and 11 are concerned with terminal sensor performance. Because this report deals with an enroute sensor exclusively, these objectives were previously verified and not considered part of this report.

4.6.3 Test Configuration.

Figure 4.6.3-1 depicts the configuration for this test.

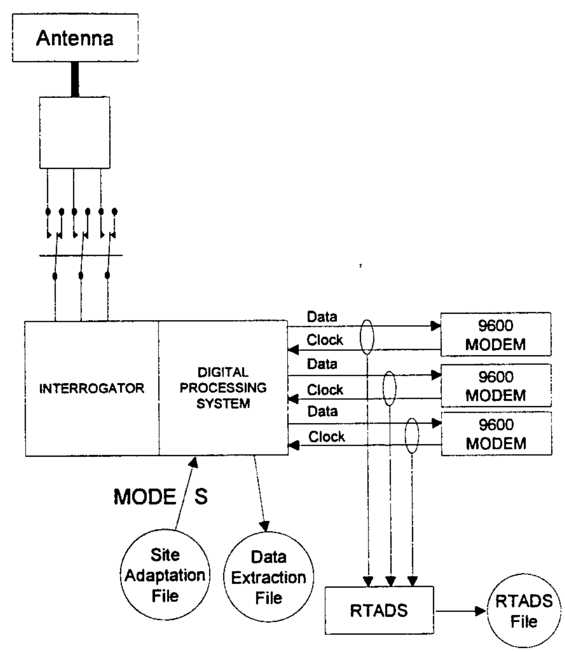


FIGURE 4.6.3-1. MODE S COVERAGE

4.6.4 Test Description.

For the tests involving live targets, sensor #136 (Elwood) was operated into the antenna to interrogate all targets within the coverage area. The five subtests involved live data collection at sensor #136 and the data collected in these subtests was compared to the results obtained in test 3 (Surveillance Baseline-Report Parameters). The baseline SAP configuration was loaded for live world data collections.

Extractions were made from the RTADS and Mode S sensor for all subtests. The Mode S extractions do not provide any data required for this test. They are recorded for use in test 8 (Mode S Reflection Analysis).

4.6.5 Data Analysis.

Reduction and analysis was performed on the extraction files using the RBAT family of programs. For subtests 1 through 5, the RBAT SA, BFTS, and Surveillance Print and Plot programs were run on each RTADS extraction file. SA provided the statistics on blip/scan ratio, ID code, and altitude code validity needed to verify objectives 1 through 3. BFTS furnished the split data needed to verify objective 4. Surveillance Print and Plot was used to create plot files to display the data.

For subtests 6, 7, and 8, the SA and Surveillance Print and Plot RBAT programs were run on the RTADS files. SA provided statistics on blip/scan ratio, ID code validity and reliability, altitude code validity and reliability, range error, and azimuth error. These statistics were used to verify objectives 5, 7, 8, and 9. The Surveillance Print and Plot program was used to create plot files to display the data.

4.6.6 Test Results.

Objectives 1 through 4 required that the Beacon Pd, ID code validity, altitude code validity, and azimuth splits data be compared to the baseline data recorded in test 3 (Surveillance Baseline-Report Parameters). In this way, data observed using live targets (test 6, subtests 1-5) will be compared to data observed using simulated targets (test 3). To make the comparison as accurate as possible, the data from these tests was compared to the data collected using a "Real World" mixed (ATCRBS and Mode S) scenario and a "Moderate FRUIT" scenario. This corresponds to subtest 6 of test 3. The average values of subtests 1 through 5 from test 6 were used for the comparison. Results of the testing are shown in figures 4.6.6-1 and 4.6.6-2.

As shown in the figures, the live target results of test 6 were very close to the simulated target results of test 3. This is very much as expected. In general, the ATCRBS results were slightly lower for test 6, while the Mode S results were virtually identical. The differences for the blip/scan ratio, and ID and altitude code validity surveillance parameters are on the order of tenths of a percentage point or less for both ATCRBS and Mode S targets. In all cases, the limits established in test 3 were met.

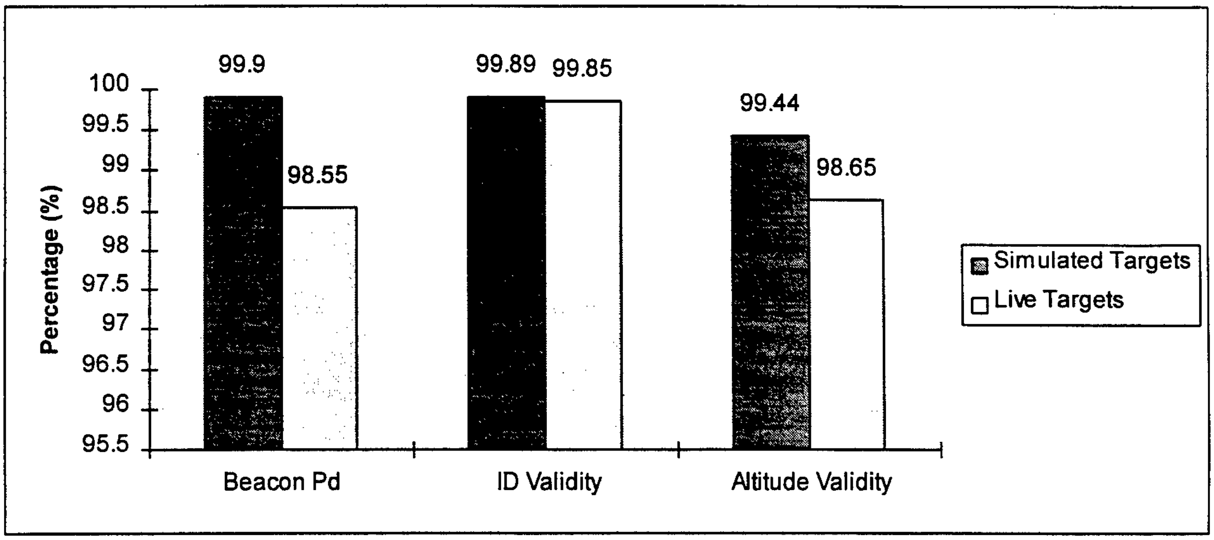


FIGURE 4.6.6-1. ATCRBS SURVEILLANCE PARAMETERS

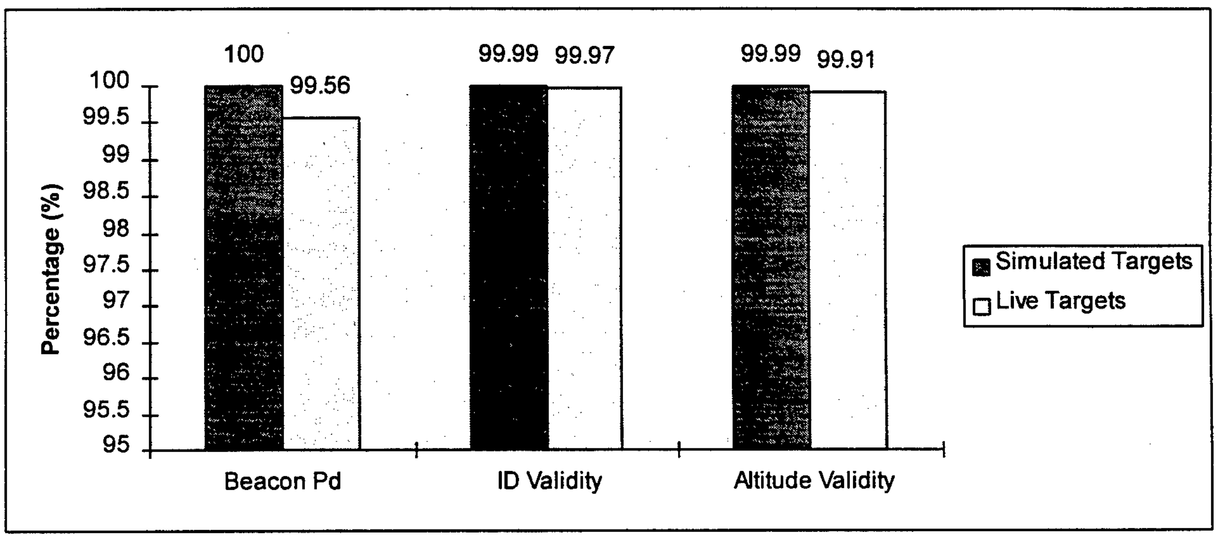


FIGURE 4.6.6-2. MODE S SURVEILLANCE PARAMETERS

A summation of the results as they relate to each objective follows.

Objective 1 required a comparison of the blip/scan ratio (Beacon Pd) data to the baseline data of test 3. The largest difference between the data from tests 6 and 4 was observed in Beacon Pd for ATCRBS targets. The 98.27 percent detection for real ATCRBS targets is 1.63 percent lower than that for simulated targets. The ATCRBS detection limit set forth in objective 1 of test 3 is 97.0 percent. The value for real targets is lower, but it still meets this limit.

Objective 2 required a comparison of the ID code validity data to the baseline data of test 3. For ATCRBS targets, the ID code validity was 99.89 percent in test 3, and 99.73 percent in test 6. For Mode S targets, the values were 99.99 percent and 99.97 percent for tests 3 and 6,

respectively. The values observed using real and simulated targets are less than 0.16 percent apart.

Objective 3 required a comparison of the altitude code validity data to the baseline data of test 3. ATCRBS targets had an altitude code validity of 99.44 percent in test 3 and 98.77 percent in test 6. The Mode S target value was 99.99 percent for test 3 and 99.91 percent for test 6. The real target data from test 6 was within 0.67 percent of the simulated target data from test 3.

Objective 4 required a comparison of the false targets due to splits data to the baseline data of test 3. In splits from ATCRBS targets, the results of test 6 were 0.07 percent, while in test 3 there were none. However, the observed value of 0.07 percent is well below the 0.3 percent limit for splits on ATCRBS targets established in objective 5 of test 3. There were no splits associated with Mode S targets in either test 6 or test 3.

The comparison of test 6 (subtests 1-5 average) and test 3 (subtest 6 results) data is summarized in form in tables 4.6.6-1 and 4.6.6-2.

TABLE 4.6.6-1. TEST 6 VERSUS TEST 3, SURVEILLANCE PARAMETERS

	BEACON Pd		ID CODE VALIDITY		ALTITUDE CODE VALIDITY	
	ATCRBS	MODE S	ATCRBS	MODE S	ATCRBS	MODE S
TEST 6	98.27	99.56	99.73	99.97	98.77	99.91
TEST 3	99.90	100	99.89	99.99	99.44	99.99
TEST 3 LIMIT	>97.0%	>98.0%	>97.0%	>99.9%	>95.0%	>99.9%
LIMIT MET?	YES	YES	YES	YES	YES	YES

TABLE 4.6.6-2. TEST 6 VERSUS TEST 3, AZIMUTH SPLITS

	AZIMUTH SPLITS	
	MODE S	ATCRBS
TEST 6	0.0%	0.07%
TEST 3	0.0%	0.0%
TEST 3 LIMIT	<0.10%	<0.30%
LIMIT MET?	YES	YES

4.6.7 Conclusions.

The sensor performed equally well with "live world" targets and simulated targets. In general, performance for ATCRBS targets was slightly degraded in real world situations, while that for Mode S targets was almost identical. This was attributed to both targets flying in the fringe coverage areas as well as weaker transponders of primarily general aviation aircraft. The Mode S targets are typically commercial aircraft flying at high altitudes. However, the sensor's performance with Mode S transponder equipped targets was virtually the same with real or simulated targets. The data for surveillance parameters and false targets observed in this test

exceeded the limits established by the objective of test 3 (Surveillance Baseline-Report Parameters). All of the enroute sensor coverage limits were verified. All of the applicable objectives listed in the test procedure have been verified, and there are no deficiencies to report for this procedure.

4.7 MODE S REFLECTION ANALYSIS.

4.7.1 Purpose.

This test measured the sensor's ability to identify reflected multipath false target reports correctly. The test used simulated targets provided by ARIES scenarios to test the Mode S adaptive thresholding. Adaptive thresholding is used to reduce false targets caused by in-beam ground-bounce reflections.

4.7.2 Test Objectives.

The objective for this test was as follows:

Objective 1: To verify that Mode S reduces false target reports that result from multipath effects.

4.7.3 Test Configuration.

Figure 4.7.3-1 depicts the configuration for this test.

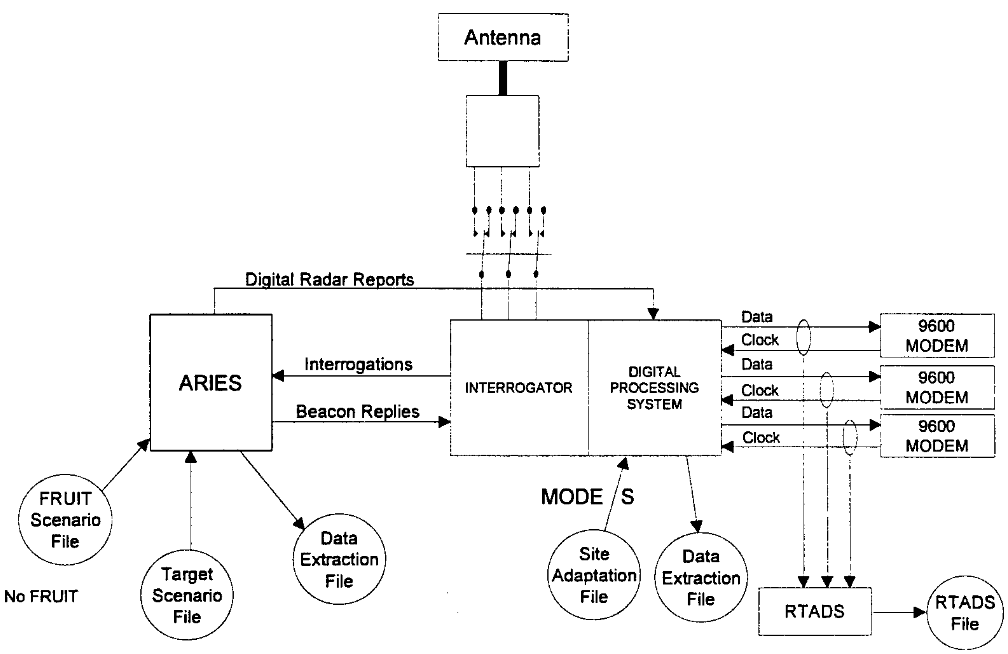


FIGURE 4.7.3-1. MODE S REFLECTION ANALYSIS

4.7.4 Test Description.

Subtests 6 through 10 used an ARIES ground-bounce scenario to determine whether adaptive thresholds reduce multipath false targets. The downlink reflection scenario was used. The downlink reflection scenario simulates ground-bounce replies and is designed to test the sensor's adaptive threshold circuitry. Pairs of moving targets were generated with the same azimuth but different ranges. The range difference of each pair was varied from completely separated to fully overlapped. Replies from the true targets were 20 dB greater than the ground-bounce reply.

This set of subtests was executed using the standard ARIES SAP configuration with the following changes:

a. mdS_rc_stc_crv_ref = 0
b. mdS_ac_stc_crv_ref = 0
c. atcr_stc_crv_ref = 0
d. aux_stc_crv_ref = 0

RTADS, ARIES, and Mode S sensor data extractions were collected.

4.7.5 Data Analysis.

The BFTS and RBAT Surveillance File Analysis programs were used to identify the number of times that a false target was identified as false in its surveillance file.

The DR ARIES/Mode S Compare program was used to identify missing reports, incorrect codes, or false targets for the ground-bounce multipath analysis.

For subtests 6 through 10, the ARIES/Mode S Compare program was executed. As the ground-bounce scenario was executed for this set of subtests, the ARIES/Mode S Compare program was used to determine how the reflected and real targets were tracked as the SAPs varied.

4.7.6 Test Results.

There was one test objective to be verified.

Objective 1 states that Mode S must reduce false target reports that result from multipath effects. This was accomplished.

Subtests 6 through 10 revealed the effect of the adaptive threshold circuitry. Adaptive thresholding works by comparing the detection threshold to the amplitude of the last pulse detected. In analyzing subtests 6 through 10, it was important to ensure that the real targets were tracked, and the reflected ones were not (depending on the adaptive thresholding value).

For this portion of the test, the STC curves were set to zero to eliminate their effect.

Table 4.7.6-1 shows the Pd data (as observed at various points within the Mode S) for real and reflected targets as the adaptive threshold was varied.

TABLE 4.7.6-1. PROBABILITY OF DETECTION, Pd (%)

Subtest	Adaptive Threshold SAP	Reply Level		Report Level		Surveillance File		Dissemination Level	
		Real	False	Real	False	Real	False	Real	False
6	15	98.88	0.94	100.00	0.70	94.03	0.00	100.00	0.00
7	20	99.20	0.94	100.00	0.72	93.34	0.00	98.61	1.76
8	25	98.55	2.99	100.00	4.19	94.05	0.00	99.65	1.41
9	30	98.74	2.22	100.00	2.49	94.03	0.00	100.00	1.43
10	None	98.98	2.99	99.65	4.19	93.71	0.37	98.61	3.84

4.7.7 Conclusions.

Subtests 6 through 10 verified that adaptive thresholding does work properly.

The objective was to verify that the Mode S reduces the number of false target reports that result from multipath effects. This was verified successfully.

The objective for this test and its verification are summarized in table 4.7.7-1.

TABLE 4.7.7-1. OBJECTIVE SUMMARY

OBJECTIVE	VERIFIED?
1. Verify that Mode S reduces false target reports due to multipath effects.	Yes

4.8 SENSOR ACCURACY.

4.8.1 Purpose.

This test measured the accuracy of Mode S position reporting, for both moving and stationary targets. The Mode S sensors Calibration and Performance Monitoring Equipment (CPME) was used as a source of Mode S and ATCRBS replies to evaluate accuracy at a low angle (less than 2°) stationary position. Since the Mode S specification specifies that bias errors are measured at low angles, and due to the fact that many aircraft transponders' delay times vary as a function of time and temperature, the CPME was used for all bias measurements. Live targets of opportunity were used for determining the overall and individual accuracy of moving targets. These tracks were analyzed by use of a nine-point sliding window algorithm.

4.8.2 Test Objectives.

The objectives for this test were as follows:

a. Objective 1: To verify that the sensor-only range errors for Mode S reports do not exceed ±30-foot bias and 25-foot root mean square (rms) jitter.

b. Objective 2: To verify that the sensor-only range errors for ATCRBS reports do not exceed ±30-foot bias and 25-foot rms jitter.

c. Objective 3: To verify that the long term combined sensor plus antenna azimuth errors for Mode S reports do not exceed:

1. A bias of ±0.033° for elevation angles less than 2° (exclusive of antenna wind load).

2. Jitter less than 0.060° (one standard deviation) for elevation angles less than 20°.

d. Objective 4: To verify that the long term combined sensor plus antenna azimuth errors for ATCRBS reports do not exceed:

1. A bias of ±0.033° for elevation angles less than 2° (exclusive of antenna wind load).

2. Jitter less than 0.060° (one standard deviation) for elevation angles less than 20°.

4.8.3 Test Configuration.

Figure 4.8.3-1 depicts the configuration for this test.

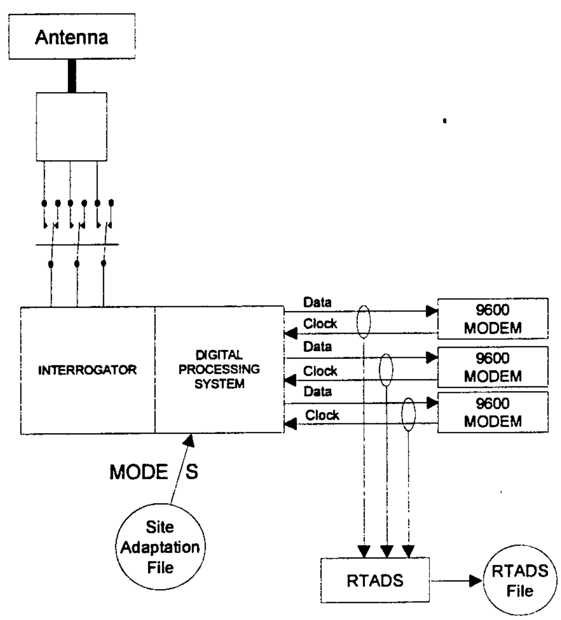


FIGURE 4.8.3-1. SENSOR ACCURACY

4.8.4 Test Description.

This test utilized both fixed surveyed targets, namely the Mode S CPMEs, and live targets of opportunity to determine the overall sensor accuracy. Neither a controlled aircraft nor a Nike/Hercules tracker was used in conducting this test. Rather, statistical analysis was used to characterize the system's accuracy performance utilizing a technique which can be employed at any site.

4.8.5 Data Analysis.

The RBAT "Mode S Fixed Transponder Accuracy" program was used to determine bias and jitter of a stationary target below 2° elevation angle. DR "Nine Point" program was also used to provide information on range and azimuth errors. This program considers the targets current position and its position over the past four scans and four scans into the future. These "nine points" are then used to construct a curve. The difference between the current position predicted by the curve fitting process and the current position reported by the sensor is considered to be the position error. The DR "Nine Point" program operates at the report level with range and azimuth resolutions of 1 Ru (30.7 feet) and 1 au (.022°), respectively.

4.8.6 Test Results.

Table 4.8.6-1 summarizes the results of the stationary target analysis, which utilized the two CPMEs associated with the Elwood Mode S. Five data collection runs were used and averaged to achieve the results. With the exception of the range bias being out of tolerance, all of the other criteria was met. A range bias of ±1 Rus (±30 feet) is desired. This test achieved ±2 Rus. CPME 0207 is the system's primary CPME and 0206 is the redundant secondary CPME, which is the reason for the azimuth bias on the latter CPME. Calibration is based only on the primary CPME. Some of the range bias can be attributed to temperature changes between the time calibration was performed and when the data was collected. Temperature changes will affect the electrical length on the cable path between the CPME and its antenna. Also, if the cables between the CPMEs and their antennas are not both the same, then the secondary CPME will have an initial bias based on the delta electrical difference in cable lengths.

TABLE 4.8.6-1. CPME ERROR DATA

CPME, Target Type	RANGE (feet)		AZIMUTH (degrees)	
	MEAN ERROR	STD-DEV	MEAN ERROR	STD-DEV
0206, ATCRBS	49.5	17.5	0.159	0.026
0206, Mode S	45.1	10.4	0.174	0.038
0207, ATCRBS	28.3	14.9	-0.027	0.040
0207, Mode S	41.8	9.9	-0.026	0.043
Average, ATCRBS	38.9	16.2	0.066	0.033
Average, Mode S	43.4	10.2	0.074	0.041
Limits	30.0	25.0	0.033	0.060

In using targets of opportunity, two approaches were taken in characterizing range and azimuth jitter. The first was to analyze selected ATCRBS and Mode S tracks that had high detection characteristics and were either flying a straight tangential or radial trajectory with respect to the radar. This is to minimize the mathematical error that would be incurred due to the limitations of the polynomial equation used in calculating the predicted position of a given track. Table 4.8.6-2 summarizes the positional errors for these tracks, which are averaged by type. A summary of the accuracy analysis data for all the targets within the coverage area of 5 to 255 nmi, 0.5° to 20° elevation angle are presented in table 4.8.6-3. Outlying points beyond a factor of 10 percent of the least significant range and azimuth bit were filtered out and pertained to less than 1.4 percent of all the samples used. This means that reports greater than 300 feet or 0.22°, typically resulting from interference situations, were discarded.

TABLE 4.8.6-2. SELECTED TRACKS, 9-POINT DATA

	SAMPLE SIZE	RANGE STD-DEV	AZIMUTH STD-DEV
ATCRBS Tangential Tracks	2362	51.7	0.038
ATCRBS Radial Tracks	868	42.8	0.040
Mode S Tangential Tracks	3627	48.8	0.043
Mode S Radial Tracks	3354	44.2	0.049
ATCRBS		47.3	0.039
LIMIT	NONE	25.0	0.060
Mode S		46.5	0.046
LIMIT	NONE	25.0	0.060

TABLE 4.8.6-3. SUMMARY 9-POINT DATA

	FILTERED OUT (%)	SAMPLES USED	RANGE JITTER STD-DEV (feet)	AZIMUTH JITTER STD-DEV (degrees)
ATCRBS	[redacted]	89,220	54.5	0.045
Mode S	[redacted]	281,886	53.7	0.044
Total	1.37%	371,106	53.9	0.045

In these subtests the range error is within ±2 Rus, yet not within the desired ±25 feet. A number of factors could contribute to the range errors. One is that the nine-point algorithm is not capable of providing absolute position, but a mathematical prediction of where a target should be at any given time in space. Another contributing factor is that since these tracks are all targets of opportunity, they are not controlled aircraft. So there is no way to account for changes in acceleration or any other maneuvering. This also would apply to any transponder response time-jitter, where a 5-percent jitter on an ATCRBS transponder would correspond to 80-foot range deviations.

4.8.7 Conclusions.

Though the Mode S at the Technical Center does appear to have a fixed range bias of about 1-2 Rus and an azimuth bias of 1-2 Aus, the range and azimuth jitter are well within desired limits. The range bias values are being attributed to the changes in environmental conditions surrounding the CPME, specifically temperature on the cable between the CPME and its antenna. As mentioned previously, this can cause changes in the propagation delays and thus biases range. With respect to the azimuth biases, there have been two different azimuth bias problems encountered at the Technical Center. The first was due directly to various reoccurring mechanical problems pertaining to the rotary joint. The second problem has not been resolved and pertains to the long-term drift of the secondary CPME with respect to the primary CPME. This drifting has been measured in the order of just under a quarter of a degree over a period of a few months. This drifting returns back to its starting point a few months later in a cyclical fashion. Though it is possible that this is also caused by mechanical jitter between the rotary joint and the antenna pedestal, additional work still needs to be done to insure that both halves of the rotary joints are firmly attached to the upper and lower antenna pedestal halves. In some enroute configurations, the primary radar's semi-flexible waveguide is all that keeps one-half of the rotary joint in place. This alone can cause azimuth shifts in the order of degrees and prevent the Mode S from operating in Mode S mode.

For a baseline analysis, though, this method of analysis does provide a reproducible means for any facility to measure the general accuracy of a radar using only targets of opportunity. These tests provide a reasonable baseline for which comparisons can be made.

4.9 SENSOR RESOLUTION.

4.9.1 Purpose.

This test verified the ability of the Mode S sensor to detect and resolve two aircraft closely spaced in range and azimuth. This procedure was primarily concerned with obtaining and comparing resolution data from ATCRBS transponders. The Mode S sensor's ability to resolve two aircraft when one or both are equipped with a Mode S transponder is not an issue, but does highlight the sensor's ability to resolve conflict targets using selective addressing in addition to monopulse techniques. The resolution data obtained will be used to establish a baseline for Mode S enroute performance.

4.9.2 Test Objectives.

The objectives of this test were as follows:

a. Determine the sensor's ability to resolve two ATCRBS targets flying in close proximity.

b. Verify the Mode S reduces garble by use of monopulse beacon operations.

4.9.3 Test Configuration.

Figure 4.9.3-1 depicts the configuration for this test.

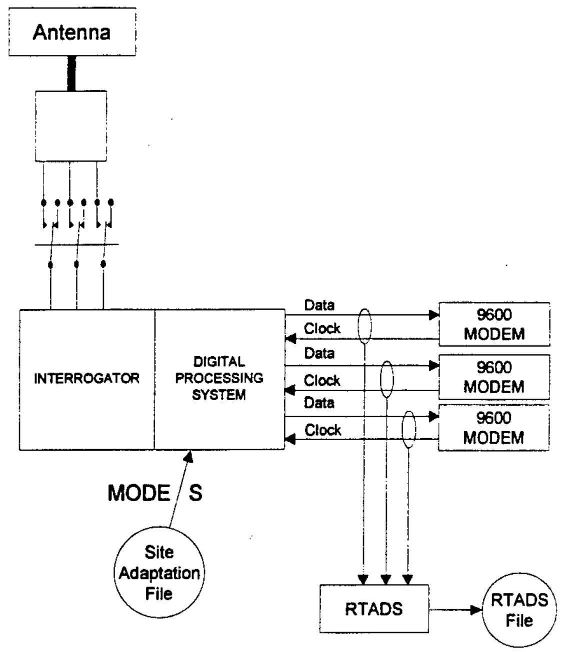


FIGURE 4.9.3-1. SENSOR RESOLUTION

4.9.4 Test Description.

These tests measured the ability of the sensor to accurately resolve target data when two or more targets are in close proximity. This was done utilizing live targets of opportunity and analyzing the sensor's tracking ability while targets are within defined conflict range, azimuth windows.

4.9.5 Data Analysis.

The data was reduced using the RBAT Conflict Analysis program. This program provided surveillance statistics for tracks while in the confines of a conflict window.

4.9.6 Test Results.

The primary objective of this test is to determine the sensor's ability to resolve targets in close proximity. Table 4.9.6-1 summarizes the results of six separate live data collection runs and includes all target conflicts, i.e., ATCRBS/Mode S, ATCRBS/ATCRBS, Mode S/Mode S. Table 4.9.6-2 summarizes only the ATCRBS/ATCRBS conflicts. The RBAT Conflict Analysis program analyzes tracks that are within a defined conflict window. Each of the conflicts constituted two or more tracks that entered within a 2 nmi by 2° window. The statistics reflect the performance of these tracks within these conflict windows. The results indicate a very high detection rate in resolving these tracks.

TABLE 4.9.6-1. OVERALL CONFLICT RESOLUTION STATISTICS

Run Description	Number of Conflicts	Sample Size (Reports)	Beacon Pd	ID Reliability	ID Confidence	Altitude Reliability	Altitude Confidence
Ch A 02/06/96	85	1868	98.13	99.51	99.89	98.94	98.71
Ch B 02/06/96	149	3041	99.11	99.64	99.80	99.10	99.04
Ch A 10/26/95	207	6224	98.52	99.23	99.66	98.69	98.63
Ch A 10/30/95	204	5831	98.34	99.37	99.86	98.01	98.14
Ch A 11/02/95	178	5826	98.56	99.74	99.83	99.42	99.48
Ch A 11/13/95	181	5420	98.56	99.66	99.85	98.30	98.69
Average	**167**	**4702**	**98.54**	**99.53**	**99.82**	**98.74**	**98.78**

TABLE 4.9.6-2. ATCRBS ONLY CONFLICT RESOLUTION STATISTICS

Run Description	Number of Conflicts	Sample Size (Reports)	Beacon Pd	ID Reliability	ID Confidence	Altitude Reliability	Altitude Confidence
Ch A 02/06/96	17	355	95.49	98.82	99.71	96.58	95.34
Ch B 02/06/96	21	375	95.20	98.32	98.88	93.31	92.36
Ch A 10/26/95	123	3428	95.92	96.02	97.60	93.36	93.22
Ch A 10/30/96	70	1755	95.33	97.73	99.52	93.48	93.27
Ch A 11/02/97	29	568	93.84	97.00	98.12	96.01	96.21
Ch A 11/13/98	79	2077	96.63	98.56	99.30	92.91	93.96
Average	**57**	**1426**	**95.40**	**97.74**	**98.86**	**94.28**	**94.06**

4.9.7 Conclusions.

This test validated the objective of resolving multiple targets in close proximity. The combined Mode S discrete interrogations and monopulse reply processing contribute to the system's ability to perform so well.

5. INTEGRATION TESTING.

The four subsections that follow in this section will address each of the four tests which were conducted, and constitute the Mode S Integration Test phase at the Technical Center. Some of the degrade testing was also conducted at the key site due to some limitations in the Technical Center NAS configuration.

It should be noted that the test plan for the integration phase was written in 1990 and that additional hardware systems referenced were under development. Those systems should now be interfacing with the Mode S, but since the Advanced Automation System (AAS) program has been canceled, the hardware configuration tested reflects the existing hardware here at the Technical Center and at the ARTCC. Since the current deployment of the Mode S does not interface to any ARSR-3 or ARSR-4 radars, these requirements have been deferred. In addition, data link functionality was not tested beyond the performance requirements validated in section 4.5.

5.1 INTEGRATION TEST CATEGORY-Q, CD-2 TO MODE S.

5.1.1 Purpose.

The purpose of this integration test was to verify the requirements related to the digital data reports transmitted from primary radar in the enroute configuration to the Mode S system.

This test demonstrated that the Mode S is capable of receiving digital communication data from the CD-2. The CD-2 provides digitized search and weather data from an ARSR-1 or ARSR-2.

The primary intent of the test was to prove the reliability of the link between the Mode S and the CD-2. The test was designed to provide a snapshot of the operation of the CD-2 and Mode S under a live world target load. Data collection was performed at the CD-2 output on the RTADS and on the Radar Intelligence Tool (RIT) for the Mode S sensor data extraction.

5.1.2 Test Objectives.

The objective for this test was as follows:

Objective 1: To verify that the Mode S sensor, when interfaced with the CD-2, is capable of accepting all messages in the standard message format as stated in the Mode S to CD-2 ICD TM-PA-0018/074/02A and Interface Requirements Document (IRD) FAA-RD-80-14A.

5.1.3 Test Configuration.

Figure 5.1.3-1 depicts the configuration for this test.

5.1.4 Test Description.

Four different Mode S/CD-2 operational configurations were selected to collect live world target data at the Elwood site. Recording the output messages from the ARSR-2 and CD-2 was conducted at the RTADS since there is no way to record messages at either of these units. The Mode S data collections were conducted on the RIT.

The first configuration was with Mode S Ch A on-line (primary) and Ch B standby with the antenna in live world and CD-2 Ch A on-line (primary) and Ch B standby. Second configuration was with Mode S Ch A on-line (primary) and Ch B standby with the antenna in live world and CD-2 Ch A standby and Ch B on-line (primary). Third configuration was with Mode S Ch A standby and Ch B on-line (primary) with the antenna in live world and CD-2 Ch A standby and Ch B on-line (primary). Fourth configuration was with Mode S Ch A standby and Ch B on-line (primary) with the antenna in live world and CD-2 Ch A on-line (primary) and Ch B standby.

For each configuration, 50 scans of data was collected, with average radar target loads of approximately 100 radar reports/scan.

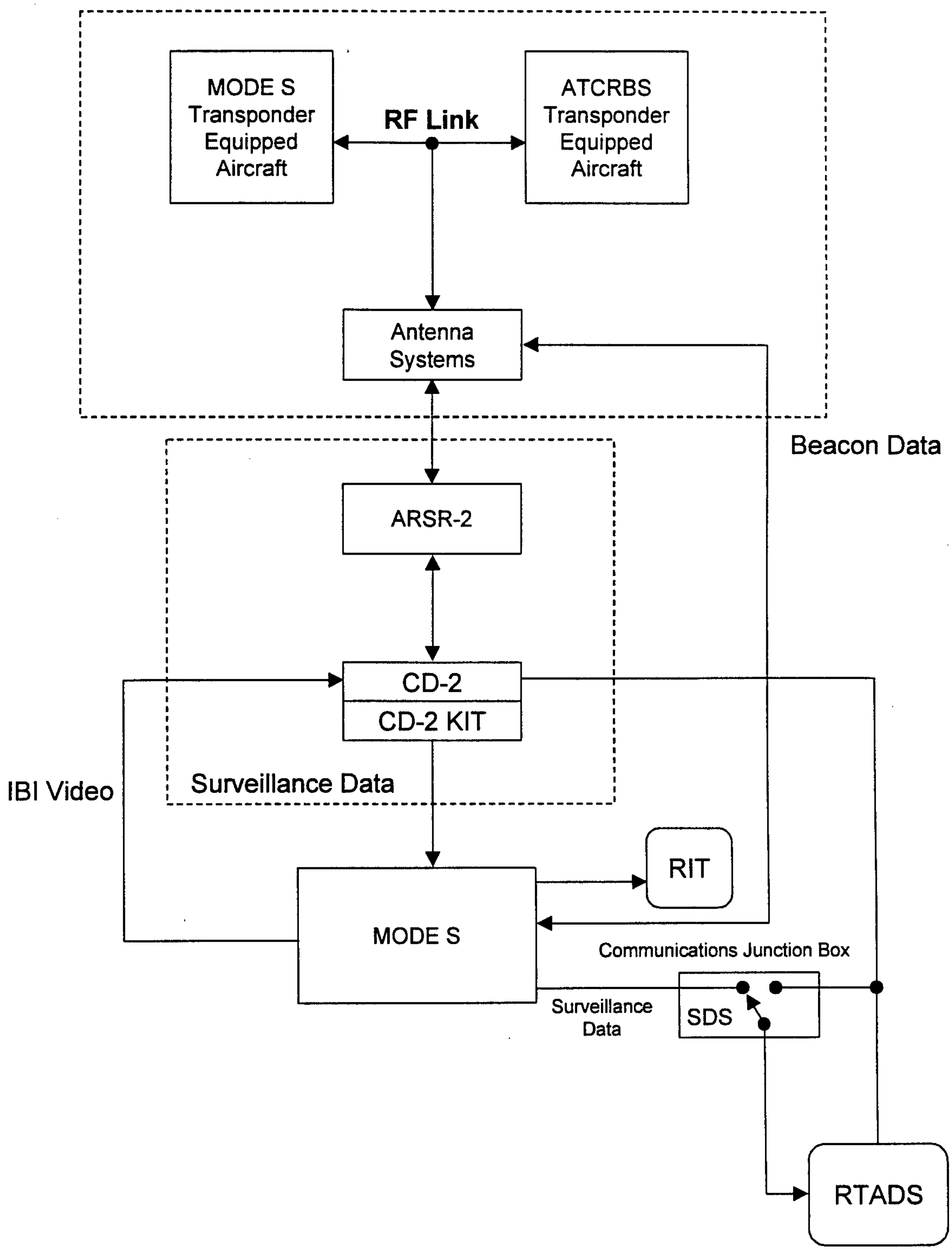


FIGURE 5.1.3-1. MODE S ARSR-2/CD-2 SURVEILLANCE INTERFACE

5.1.5 Data Analysis.

Analysis was performed on the extractions identified above using the Enroute Compare program to ensure the 100 percent correlation, i.e., all messages sent by the CD-2 are received by the Mode S. The RBAT Surveillance Print program was used to provide message listings needed to complete the ICD field verification.

5.1.6 Test Results.

One test objective was verified.

Objective 1 states that the Radar and Real Time Quality Control (RTQC) messages sent by the ARSR-2/CD-2 to the Mode S sensor shall be the correct format and size. In addition, the messages sent should match with those received by the Mode S sensor. The correlation of these messages should be 100 percent to meet the success criteria, thus demonstrating that the Mode S sensor can successfully receive Radar and RTQC messages.

To complete the verification of the first requirement, it had to be shown that the messages from the CD-2 to the Mode S contain the information fields specified in the Mode S/CD-2 ICD. Output listings from the Enroute Compare and RBAT Surveillance Print programs were used to verify that the radar message reports and the search RTQC contained the fields specified in the ICD. Analysis of the data extractions verified that the Mode S correctly received the following message types: Radar Strobe, Radar Target, Radar Status, and Search RTQC.

Proving the second part of the requirement was to show that the message types could be reliably transferred across the interface. To demonstrate this reliability, the Mode S and RTADS Data Extraction (DE) files were inputs to the Enroute Compare program. The results of the compare program show that 100 percent of the messages sent from the CD-2 correlated with messages received by the Mode S. The results of the data analysis using the Enroute Compare program is presented in table 5.1.6-1.

TABLE 5.1.6-1. MESSAGE TRAFFIC TOTALS FROM THE ARSR-2/CD-2 TO THE MODE S

Message Type	Total Correlated	Uncorrelated at Mode S	Uncorrelated at CD-2
Mode S Ch A, CD-2 Ch A			
Radar Strobe	433	0	0
Radar Target	2544	0	0
Search RTQC	41	0	0
Radar Status	41	0	0
Total	3059	0	0
Mode S Ch A, CD-2 Ch B			
Radar Strobe	0	0	0
Radar Target	5764	0	0
Search RTQC	83	0	0
Radar Status	84	0	0
Total	5931	0	0
Mode S Ch B, CD-2 Ch A			
Radar Strobe	1198	0	0
Radar Target	6108	0	0
Search RTQC	109	0	0
Radar Status	110	0	0
Total	7525	0	0
Mode S Ch B, CD-2 Ch B			
Radar Strobe	0	0	0
Radar Target	8528	0	0
Search RTQC	116	0	0
Radar Status	116	0	0
Total	8760	0	0

5.1.7 Conclusions.

This test has proven that the sensor has met the requirements defined for this test. These requirements were proven in terms of objective subjected to success criteria.

To summarize, the Mode S correctly handled most of the information received from the CD-2 properly. Two items of concern deal with search RTQC and status message processing. It was determined that the CD-2's modem adapter further processes the RTQC message after the point where the Mode S extracts from within the CD-2. The CD-2's modem adapter verifies that the RTQC message content (range, azimuth, and runlength) is within tolerance, then adjusts the message to a nominal value. The second issue relates to status message handling. The CD-2 transmits a status message once a scan plus any time a status change occurs. The Mode S transmits only once a scan, so any previous status messages received in a scan from the CD-2 are superseded by the status message received closest to the Mode S status message transmission.

The lack of search RTQC post-processing may only be a problem if the CD-2's tolerance window is larger than the HOST's, in which case the radar may be automatically taken out of service. The status message issue means that any short-term alarms that clear themselves within a scan may not be detected in the surveillance data status message, but that information should be provided by the CD-2's RMMS link to the MPS. These two issues are addressed in PTRs 10286329V and 10286331V, respectively.

5.2 INTEGRATION TEST CATEGORY-R, MODE S TO HOST.

5.2.1 Purpose.

This test demonstrated that the Mode S subsystem is capable of providing the appropriate surveillance data (via the Mode S sensor) to the HOST subsystem.

Surveillance data was generated from live world. The Mode S/CD-2/ARSR-2 systems provided the appropriate surveillance data (via the Mode S sensor) to the HOST.

Data was collected on the HOST and Mode S systems. Surveillance output data of the CD-2 was collected by an RTADS. Another RTADS was used to collect data being fed to the HOST.

Each test was run twice on each channel of the Mode S system, with each CD-2 channel being selected as well.

5.2.2 Test Objectives.

a. Objective 1: To verify that the HOST processing systems, along with the Mode S subsystem, provide surveillance services for enroute airspace; that is, the ability to provide identification and special position on ATCRBS-equipped or Mode S-equipped aircraft within a specified update rate.

b. Objective 2: To verify that the Mode S is capable of transmitting status and synchronization messages to the HOST in the proper format and size.

c. Objective 3: To verify that the Mode S subsystem configuration is capable of preparing and transmitting search radar only surveillance data messages to HOST in the proper format and size as stated in the Mode S/Air Traffic Control (ATC) Surveillance Link to ATC Enroute Facilities ICD TM-PA-0018/075/02A and IRD FAA-RD-80-14A.

d. Objective 4: To verify that the Mode S subsystem configuration is capable of preparing and transmitting beacon only surveillance data messages to HOST in proper format and size as stated in the Mode S/ATC Surveillance Link to ATC Enroute Facilities ICD TM-PA-0018/075/02A and IRD FAA-RD-80-14A.

e. Objective 5: To verify that the Mode S subsystem configuration is capable of preparing and transmitting beacon/radar reinforced surveillance data to HOST in the proper format and size as stated in the Mode S/ATC Surveillance Link to ATC Enroute Facilities ICD TM-PA-0018/075/02A and IRD FAA-RD-80-14A.

f. Objective 6: To verify that the Mode S subsystem configuration is correctly processing and routing responses from airborne transponders to HOST.

5.2.3 Test Configuration.

Figure 5.2.3-1 depicts the configuration for this test.

5.2.4 Test Description.

To verify the requirements of this test, live world data was collected utilizing the Elwood Mode S and the Technical Center HOST system.

The four different Mode S/CD-2 operational configurations that were selected in Test Category Q to collect live world target data were also used for this test. Recording the output messages from the CD-2 was conducted at the RTADS. Mode S data extractions were made at the RIT and RTADS, and on the HOST. The output files are Mode S DE, RTADS CD, and Online Radar Recording (ORR) from the HOST.

5.2.5 Data Analysis.

RBAT BFTS, SA, and Fixed Transponder Accuracy programs were used to analyze the test output results verifying that beacon/radar data was sent to the HOST.

Analysis was performed on the extractions identified above using the CD Compare and Enroute Compare programs to ensure the 100 percent correlation. The RBAT Surveillance Print program was used to provide message listings needed to complete the ICD field verification.

5.2.6 Test Results.

a. Objective 1: Validation of the objective was accomplished by reducing extracted data files; producing reports from Track Level Analysis, Plots/Listings, and ORR from HOST. The test objective was verified with the successful demonstration that the Mode S subsystem can provide acceptable surveillance coverage for the enroute aircraft environment of the Technical Center.

b. Objective 2: Validation of the objective was accomplished by matching all of the status reports transmitted by the Mode S subsystem to the HOST with those recorded by the RIT unit connected at the Mode S. The correlation of these messages is 100 percent and meets the success criteria, thus demonstrating that the Mode S subsystem can successfully provide these messages to the HOST. The synchronization messages were validated both with an oscilloscope and by virtue of the fact that none of the data receivers will properly process any data unless the synchronization messages are proper.

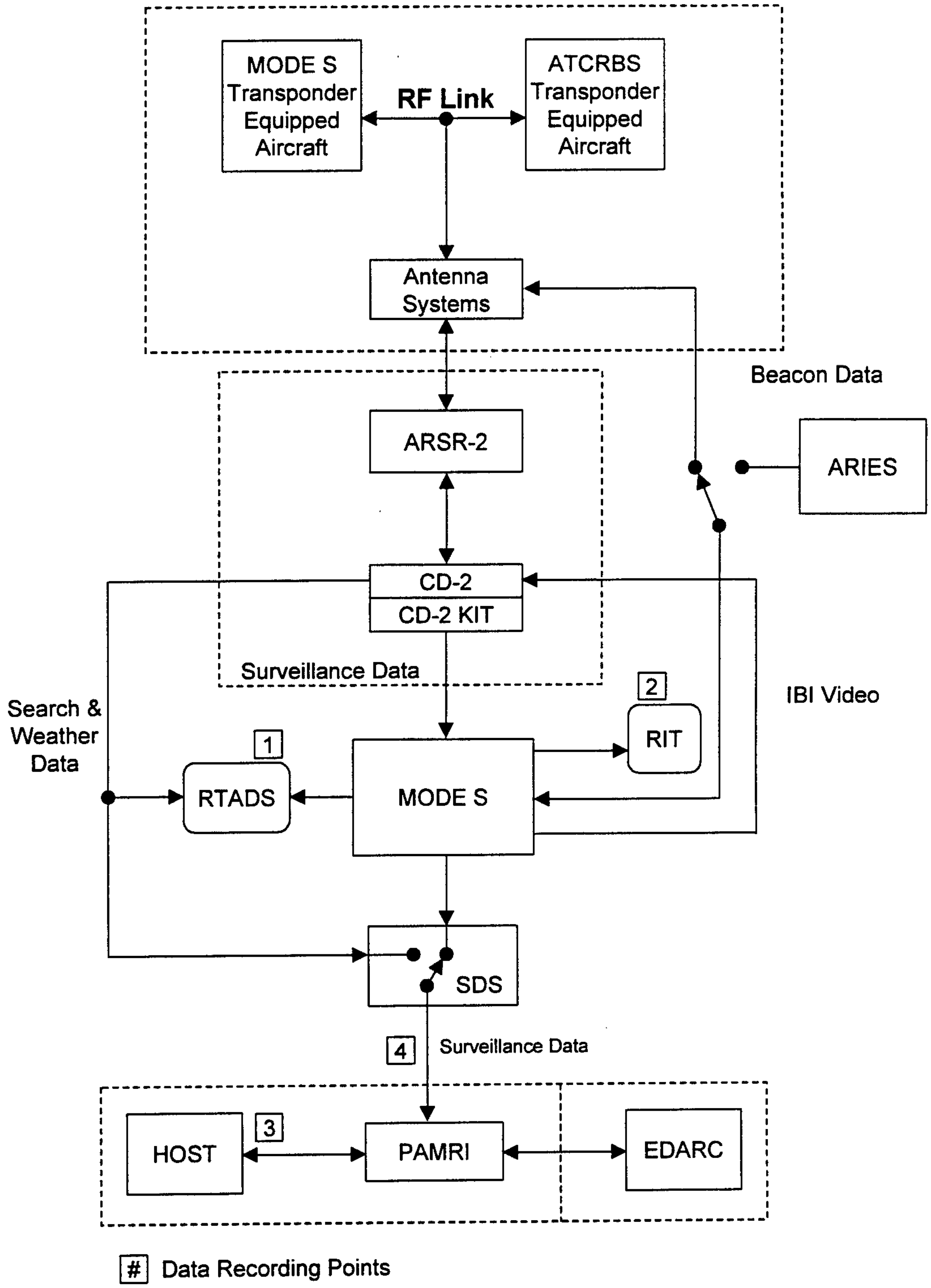


FIGURE 5.2.3-1. MODE S ARSR-2/CD-2 TO HOST

c. Objective 3: Validation of the objective was accomplished by matching all of the search radar data, radar strobe reports, and search RTQC reports transmitted by the Mode S subsystem to the HOST with those recorded by the RIT unit connected at the Mode S. The correlation of these messages is 100 percent and meets the success criteria, thus demonstrating that the Mode S subsystem can successfully provide these messages to the HOST. The results of the compare program are presented in table 5.2.6-1. The format and size of these messages was verified in accordance with FAA-RD-80-14A.

d. Objective 4: Validation of the objective was accomplished by matching all of the beacon radar data, beacon RTQC reports, beacon status reports, and beacon strobe reports transmitted by the Mode S sensor to the data received by the HOST. Data comparisons were made on data files extracted on the RTADS, RIT, and the ORR. The correlation of these messages is 100 percent, except for the Beacon Strobe reports, which meets the success criteria. The Beacon Strobe reports are purposely suppressed within the Mode S by SAPs and are not transferred to the HOST by default. The results of the compare program are presented in table 5.2.6-1. The format and size of these messages were verified in accordance with FAA-RD-80-14A.

e. Objective 5: Validation of the objective was accomplished by matching all of the Beacon/Radar Reinforced reports and Beacon Radar Status reports transmitted by the Mode S subsystem to the data received at the HOST. Data comparisons were made on data files extracted on the RIT and the ORR. The correlation of these messages is 100 percent and meets the success criteria. This demonstrates that the Mode S subsystem can successfully provide beacon/radar-reinforced data to the HOST, and all targets within the surveillance coverage of the Mode S sensor are updated once every antenna scan. The results of the compare program are presented in table 5.2.6-1. The format and size of these messages were verified in accordance with FAA-RD-80-14A.

f. Objective 6: Validation of the objective was accomplished by matching all of the Beacon reports transmitted by the Mode S subsystem to the data received at the HOST. Data comparisons were made on data files extracted on the RTADS, RIT, and the ORR. The correlation of these messages is 100 percent and meets the success criteria, thus demonstrating that the Mode S subsystem can successfully provide beacon/radar reinforced data to the HOST, and verifying that reports on all targets within the surveillance coverage of the Mode S sensor are updated once every antenna scan.

The test objective was verified when the following conditions were met. Demonstration that the HOST received appropriate beacon surveillance data (identification and special position) for coverage of the enroute aircraft environment of the Technical Center updated each scan.

These messages were compared to the ICD formats and were observed to contain the fields specified by the ICD. The data that filled these fields was verified as appropriate for the conditions under which the test was executed, at least to the point that such verification was possible.

TABLE 5.2.6-1. MESSAGE TRAFFIC TOTALS FROM THE MODE S TO THE HOST

Message Type	Total Correlated	Uncorrelated at Mode S	Uncorrelated at HOST
Mode S Ch A, CD-2 Ch A			
Radar Strobe	442	0	0
Beacon Strobe	0	801	0
Search Target	2611	0	0
Beacon Radar Target	6520	0	0
Beacon RTQC	43	0	0
Search RTQC	42	0	0
Beacon Status	N/A	N/A	N/A
Beacon/Radar Status	42	0	0
Beacon/Radar Reinforced	6448	0	0
Total	**16148**	**801**	**0**
Mode S Ch A, CD-2 Ch B			
Radar Strobe	0	0	0
Beacon Strobe	0	1662	0
Search Target	5563	0	0
Beacon Radar Target	11374	0	0
Beacon RTQC	80	0	0
Search RTQC	81	0	0
Beacon Status	N/A	N/A	N/A
Beacon/Radar Status	81	0	0
Beacon/Radar Reinforced	14468	0	0
Total	**31647**	**1662**	**0**
Mode S Ch B, CD-2 Ch A			
Radar Strobe	1194	0	0
Beacon Strobe	0	1730	0
Search Target	6084	0	0
Beacon Radar Target	17399	0	0
Beacon RTQC	109	0	0
Search RTQC	109	0	0
Beacon Status	N/A	N/A	N/A
Beacon/Radar Status	109	0	0
Beacon/Radar Reinforced	18324	0	0
Total	**43328**	**1730**	**0**
Mode S Ch B, CD-2 Ch B			
Radar Strobe	0	0	0
Beacon Strobe	0	1974	0
Search Target	8527	0	0
Beacon Radar Target	17154	0	0
Beacon RTQC	116	0	0
Search RTQC	116	0	0
Beacon Status	N/A	N/A	N/A
Beacon/Radar Status	116	0	0
Beacon/Radar Reinforced	21084	0	0
Total	**47113**	**1974**	**0**

5.2.7 Conclusions.

This test has proven that the sensor has met the requirements defined for this test. These requirements were proven in terms of their test objectives and success criteria. The beacon strobe messages are purposely suppressed within the Mode S. Under the defined requirements of the Mode S specification, the Mode S generates a significant number of beacon strobe messages. These messages are the result of more than four simultaneous ATCRBS replies being detected by the Mode S Interrogator in a FRUIT environment. The messages can be transmitted to the HOST and processed properly, but their continued existence on the HOST does cause target loss. For this reason, the Mode S was modified to selectively suppress two of the three conditions which cause the strobes to occur. The first is the detection of more than four ATCRBS replies simultaneously and the second condition is the detection of more than 45 replies in any given sweep. Neither one of these conditions should cause any significant data degradation at the target report level, which was proven in the performance tests.

5.3 INTEGRATION TEST CATEGORY-V FULL-UP SYSTEM.

5.3.1 Purpose.

The purpose of this test was to evaluate the Mode S capabilities in an enroute environment as near an operational state as attainable. This test demonstrated that the Mode S subsystem is capable of providing the appropriate surveillance data within an enroute system configuration. End-to-end response time, data accuracy, timely data exchanges, and capacity load levels will be verified during this test. Also included in this test category was an evaluation of how the system's normal operation is maintained, when the Mode S channels are switched, and when the mode of operation is switched or degraded to ATCRBS backup mode.

5.3.2 Test Objective.

The objectives for this test were as follows:

a. Objective 1: To evaluate if the Mode S can physically interface, as well as exchange data timely and accurately with the following interfaces while they are simultaneously operational:

1. Airborne Mode S/ATCRBS Transponders
2. (ARSR-1, ARSR-2, or FPS)/CD-2
3. Remote Terminal (RT)
4. Mode S Interim Monitoring and Control Terminal (MSIMC)
5. Local Maintenance Terminal (LMT)
6. HOST/DARC

b. Objective 2: To evaluate the capability of the Mode S to operate under high capacity load conditions in an operational configuration.

c. Objective 3: Access the impact on system level operations when the Mode S sensor is switched from the primary channel to the backup channel.

d. Objective 4: Access the impact on system level operations in the event that the Mode S processor fails and the ATCRBS backup is utilized.

5.3.3 Test Configuration.

Figure 5.3.3-1 depicts the configuration for this test.

5.3.4 Capacity and Throughput.

5.3.4.1 Subtest Description.

Target capacity and throughput was tested to ascertain whether the Mode S sensor, functioning as part of a CD-2/Mode S/HOST-DARC configuration, is capable of handling the NAS specified target capacity and target distribution within the specified time constraints. Since there was no way of recording data within the HOST with precision time-of-year information, data was recorded at the input to the PAMRI with an RTADS equipped with a time-of-year interface board. Time tagged data was also recorded at the ARIES, Mode S, and a local RTADS. The ARIES was used to simulate a 700 target scenario with moderate FRUIT and provide an additional 1000 radar targets (700 correlated + 300 radar only). Under the current NAS configuration, the surveillance outputs of the Mode S are limited to three 2,400-baud modem lines (7,200 baud total). For comparison, data from the data link performance tests was also used for capacity throughput statistic with the surveillance output configured to three 9,600-baud lines (28,800 baud total).

5.3.4.2 Analysis.

The DR programs "Throughput Analysis" and "Surveillance Analysis," as well as the RBAT "Surveillance Analysis" program, were used to reduce and analyze the data from these tests. The two different surveillance analysis programs were used to measure the impact of data throttling. DR looks at all of the track reports; RBAT can only process reports that are not throttled. Since the maximum data throughput at 3 x 2400 transmissions is approximately 650 beacon target reports, Pd will be affected at the dissemination level.

5.3.4.3 Subtest Results.

The data throughput exceeds the limits set forth in the NAS-SS-1000 requirements, which is 1.5 seconds from the Mode S through to the input of the modems. These limits cannot be met until the transmission line restriction imposed by the DARC system is released and the data rates are increased to at least 3 x 9600 = 28,800 bits per second (bps). Figure 5.3.4.3-1 illustrates the data delays at target loads of 250, 400, and 700. The far left curve, which fits between 0.7 and 1.0 seconds, is the throughput delay of a 700 target scenario with full data link capacity loading, but operating at a 28,800 bps modem rate.

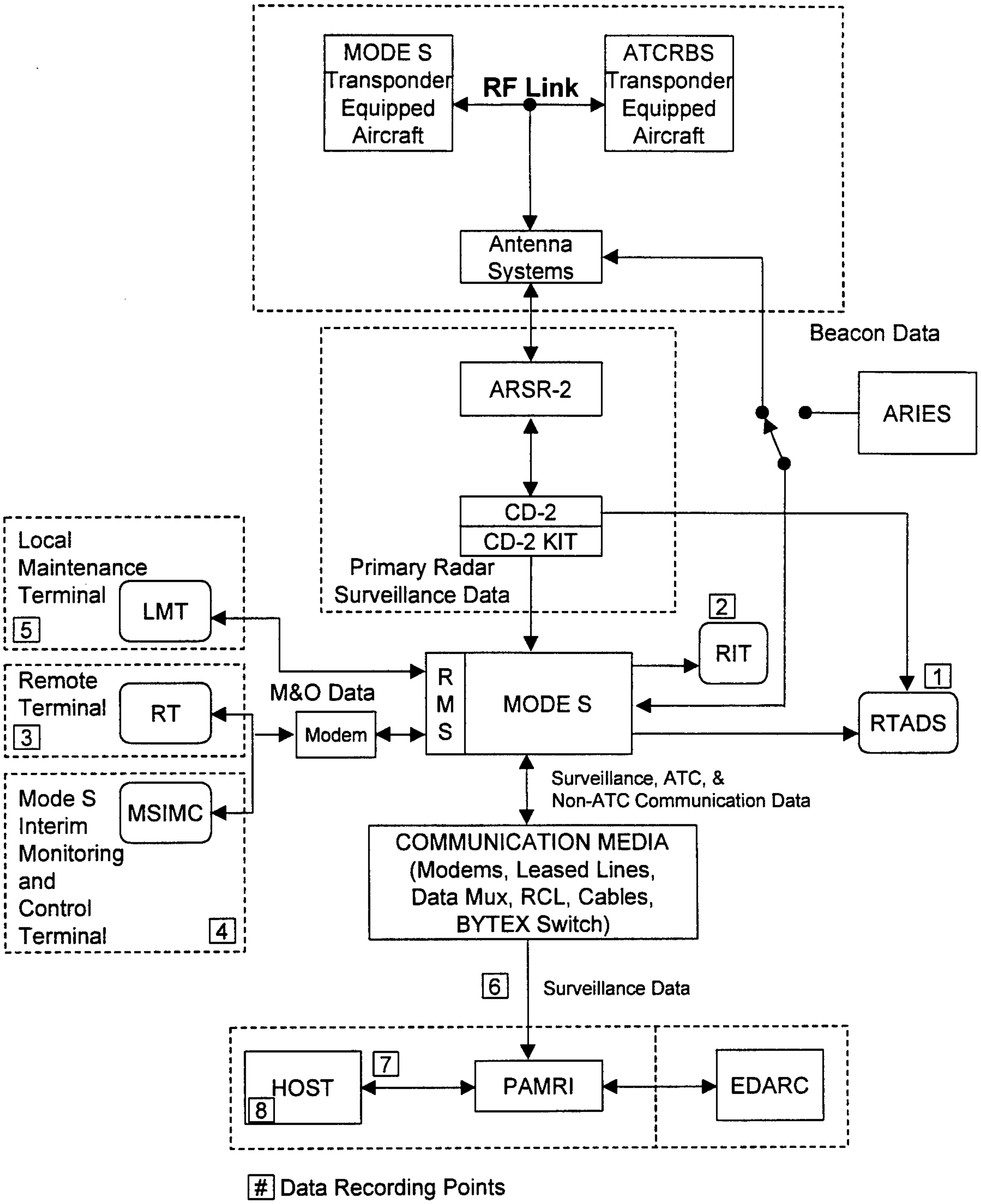


FIGURE 5.3.3-1. FULL-UP CONFIGURATION SYSTEM

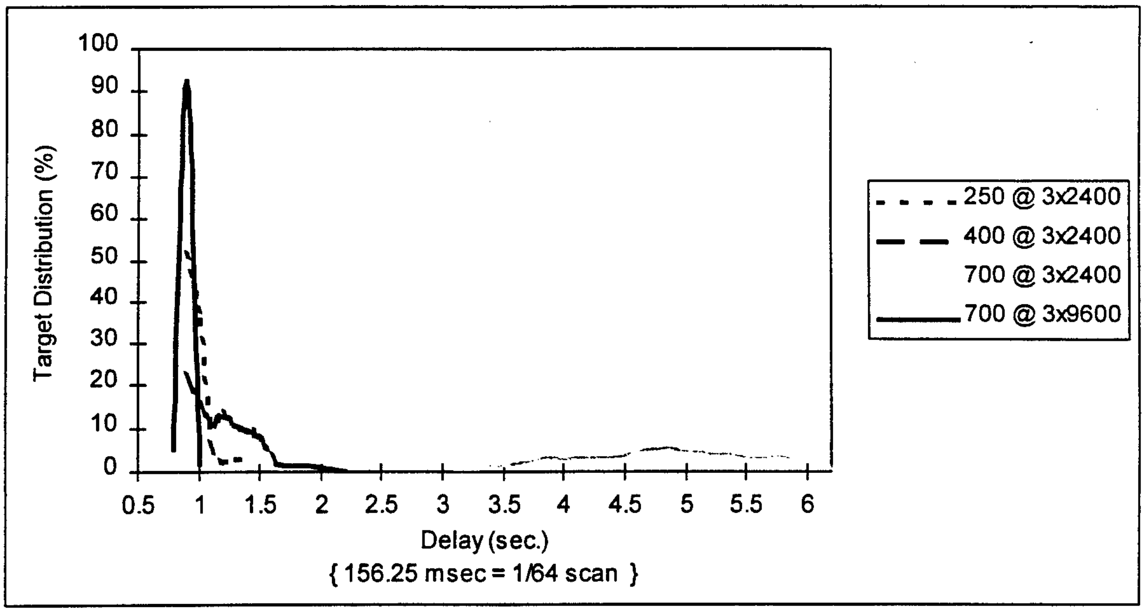


FIGURE 5.3.4.3-1. MODE S THROUGHPUT, BORESIGHT-TO-MODEM DELAYS

The measured communication data delay from the output of the Mode S to the input to the NAS automation equipment at the Technical Center was measured to be 0.3 seconds, which is the NAS-1000 requirement. This delay though is a more site-to-ARTCC specific value. The Technical Center communication configuration consisted of digital Codex modems feeding at 56 kilobits per second (kbps) a Newbridge T-1 multiplexer.

The predictable result of the capacity scenario was that when the target load exceeded approximately 650 targets, beacon data began to degrade. This is intentionally done by the Mode S to accommodate the 2,400-baud line restriction placed on NAS input by the DARC system. The DARC input bandwidth per radar facility is 7,200 bps (3 x 2,400). The Mode S properly throttles data as a function of buffer loading and time in storage. The system first sheds weather and search-only data based on site adaptable threshold levels. Nonpriority beacon messages are only shed when the buffer capacity exceeds 98 percent. Priority beacon messages are defined as RTQC, status and emergency code (7700, 7600) messages.

The 650 target limit is based on the Mode S capacity scenario which tests the specification limits of the system. This is a worst case scenario, placing a majority of the 700 targets in one quadrant and operating at a 10-second scan rate.

The capacity summary statistics are listed in table 5.3.4.3-1. The statistics present are meant to point out the degradation of the effective Pd that ATC would experience. Note that the Pd drops almost 2 percent under the peak loading.

TABLE 5.3.4.3-1. STATISTICS FOR CAPACITY TEST

Test	Pd	ID Reliability	ID Confidence	Altitude Reliability	Altitude Confidence	Samples
Entire Scenario prior to dissemination	99.94	99.45	99.36	99.67	99.96	69788
Entire Scenario after dissemination	98.10	99.78	99.87	99.72	99.73	68873
Peak 700 target plateau of scenario prior to dissemination to ATC	99.98	99.74	98.74	99.72	98.17	29392
Peak 700 target plateau of scenario after dissemination to ATC	97.1	99.89	99.94	99.74	99.76	28762

5.3.5 Degrade and Maintenance Scripts.

5.3.5.1 Subtest Description.

The conduct of the degrade tests occurred formally at the key site. The scripts were also run at Elwood, but the overall configuration at the Technical Center did not adequately allow for the System Maintenance Monitor Console (SMMC) maintenance script to be executed. The nine normal and degraded maintenance Mode S system operational procedures that were conducted tested the following operations and functions:

a. Mode S Channel Switches - Basic Mode S channel changes initiated from the RT.

b. CD-2 Channel Switches - Basic channel changes on the CD-2.

c. Mode S On-site Maintenance - Alarm condition induced and corrected via Local Terminal (LT).

d. CD-2 Maintenance - Alarm condition induced and corrected on site.

e. Mode S Remote Maintenance - Alarm condition induced and corrected via Mode S Interim Maintenance Console.

f. SMMC Maintenance for CD-2 - CD-2 maintenance action performed from ARTCC.

g. Mode S Cold Starts - Power up sequence of the Mode S.

h. Mode S/CD-2 Short Power Failures - Short duration power outage of both systems simultaneously.

i. Mode S to IBI Channel Switches at RT - Mode S to IBI and IBI to Mode S mode changes.

5.3.5.2 Subtest Results.

In general, the following list summarizes normal transitions between various modes of operation:

a. Mode S channel changes - Mode S channel changes, caused by either manual user intervention or automatically because of a detected fault, resulted in less than a 90° target loss.

b. Mode S to IBI mode transitions – Transitions from Mode S mode into IBI normally caused a target loss of approximately 30°.

c. IBI to Mode S mode transitions – Transitions from IBI to Mode S mode generally resulted in less than 360° of target loss.

d. CD-2 operations on the Mode S – The CD-2 had no major effect on the Mode S in disturbing the flow of surveillance data. Channel changes, initializations, power outages of the CD-2, at most, caused "Yellow" alarm conditions on the Radar Line Adapter RMS Logical Unit (LU) data point of the Mode S. Under the current software release, the Mode S does not do any search RTQC processing. The result is that if the CD-2 does not generate a search RTQC, the Mode S will not synthetically generate one in its place. This is currently a problem for the NAS automation equipment, which requires a search RTQC each and every scan. A Program Technical Report (PTR) and a case file have been generated to allow Mode S to synthetically generate a search RTQC, both for when the CD-2 is not able to provide one and in the beacon-only configurations (PTR: 10286329V).

e. Short power failures – Short power failures (~ 5 seconds) of the Mode S resulted in an overall target loss of 180°. Actual loss of Mode S data is between two to three scans, but during the Mode S recovery it is providing IBI video to the CD-2, which provides beacon dissemination for two to three scans until the Mode S returns to Mode S mode. Short power failures of the CD-2 resulted in no loss of beacon targets. (Search and weather messages are obviously lost while the CD-2 reinitializes.) Short power failures of both systems resulted in a loss of two to three scans of beacon data.

f. Mode S resets and cold startups – Upon startup or immediately following a reset, the Mode S front-end interrogators provided beacon video to the CD-2. The Mode S remained in this mode until all initializations and startup diagnostics were complete. When the Mode S was ready to go into Mode S mode, it took control of the SDS switch and terminated the video output to the CD-2. Target dissemination was interrupted for approximately one scan as the system transitioned into Mode S mode.

In executing one of the maintenance scripts on the Mode S at the key site, a low transmit power condition was induced into the on-line channel by adding attenuation to the directional transmit path. This resulted in a hard alarm on that channel. Instead of immediately auto switching to the alternate channel and placing the faulted channel into fault isolation test (FIT), the channel remained red, on-line, in Mode S mode for 2½ minutes. After this interval of time, the channel change occurred and the channel went into FIT. This is an outstanding issue from terminal and enroute IBI testing. It is a semi-repeatable problem, occurring approximately 50 percent of the time.

5.3.6 Test Results.

a. Objective 1: This objective was accomplished by reducing extracted data and comparing the data and clock timing from the RTADS (local and remote), Mode S, and ARIES. There was degradation in timeliness under capacity loading due to limitation imposed by the current NAS configuration. These limitations are the restriction placed on data line speeds, which cannot exceed three lines operating at 2,400 bps. The Mode S can successfully meet this objective once the modem speeds can be increased to at least 9,600 bps.

b. Objective 2: This objective was accomplished by matching all of the targets generated by the ARIES scenario with those that are sent to the HOST by the Mode S sensor. Similar to objective 1, there was a degradation of data under capacity loading due to the line speed limitation. With the capacity scenarios executed, the capacity ceiling is about 650 targets. The Mode S can successfully meet this objective once the modem speeds can be increased to at least 9,600 bps.

c. Objective 3: The test objective was verified with the successful demonstration that data integrity is preserved, by the Mode S, during a switch from the primary channel to the backup channel, with minimal target loss.

d. Objective 4: The test objective was verified when the operational impact of both Mode S channels failing and the Mode S sensor reverting to the ATCRBS mode of operation was demonstrated, with minimal loss of target data.

5.3.7 Conclusions.

The current limitation in throughput and capacity are actually a NAS limitation. The performance of the system operating at 3 x 9,600 bps data channels was proven in the performance tests addressed in section 4.0. Overall, even at the current line speeds, the degradation of data is minimal at the track level.

The system performs quite well in providing surveillance data to NAS. The ability of the CD-2 to provide backup services during degrade modes and during Mode S initialization reduces further the likelihood of a facility outage.

The on-line red condition, though obviously not a desired mode to be in, is not considered a major deficiency. The likelihood of the power degrading from a green status directly to red is low. The effect of running the Mode S red on-line for this 2½ minutes would have an impact on detecting distant and fringe targets. The extent of the target loss would be determined by the overall drop in power transmitted. Also, the channel can be manually switched to the alternate channel by a System Engineer (SE) once the alarm condition appears on the RT located by the SMMC at the ARTCC. This problem (PTR: 8296244V) is slated to be fixed in the national upgrade release of the Mode S (TU0x).

5.4 INTEGRATION ISSUES.

5.4.1 Mode S Rotary Joint 14-bit Azimuth Pulse Generators.

From the start of integration of the Mode S in the enroute environment, it was recognized that the quality of the 14-bit azimuth data was going to be a problem; specifically, the 14-bit data provided by the encoders, which are located within the rotary joint assembly. These encoders were being degraded by RF interference (RFI). Both the Mode S and the primary radar contribute to this interference, though the FPS radars appear to provide additional RFI than the ARSR sites. This RFI causes the electronic logic within the encoders to generate additional false azimuth pulses. Considerable time and effort have been put into resolving the problem through both hardware and software measures. A hardware conditioning circuit was developed to generate the 14-bit data from the 12-bit data, which was not affected by the RFI. This circuit was installed in the azimuth pulse generator (APG) distribution box located in the radar equipment room. Additional logic was also incorporated into the Mode S operational software (TE00.5) to provide a level of site adaptable tolerance within the system. This will handle any spurious, infrequent anomalies in the azimuth data that may be induced between the conditioning circuit drivers and the Mode S signal processor.

5.4.2 Clock Box Interface Incompatibilities.

The Clock Box is a communications subsystem that was designed to be integrated between a Common Digitizer (CD-1 and CD-2) and the modems. It provides a precision redundant clock source, capabilities to drive multiple ATC facilities, and adds site and channel ID information on each surveillance line. The foremost concern with this device, as it pertains to being integrated with a Mode S, is that it prohibits the use of modem control signals since its inputs are BNC type connectors only. All of the newer generation radars, Mode S specifically, provide data output via an industry standard interface that requires use of hardware control/handshaking signals. In order to connect a clock box to a Mode S, the controls signals between the Mode S and the modems need to be over-ridden. The Mode S therefore will not fault due to an interface alarm. This circumvents the safety features designed into the Mode S to detect a line failure and reroute surveillance data to alternate data paths. An alternative to connecting the clock box to the Mode S systems is to modify the Mode S software to insert and transmit the site and modem channel ID messages. This would replace the Clock Box functionality in the data path. The Mode S was also designed to accommodate up to six different surveillance facilities at its output which may be required.

5.4.3 Calibration Problem.

The final portion of the optimization process at the St. Albans site involved calibrating the Mode S to the CPME. Considerable difficulty was experienced in achieving a successful build of the off-boresight table. The final determination to the cause of the problem was attributed to the CPME's transmitter being overdriven resulting in exceeding the CPME transmitter duty cycle. This was due to the default calibration pulse repetition frequency (PRF) of the Mode S. The solution was to double the pulse repetition interval (PRI), thus reducing the number of expected replies per beam dwell by half. The setting of the PRI will need to be scaled at each facility according to scan rate and beam width to ensure that the CPMEs are operated within their limits.

5.4.4 RF Interference on System and Subsystems.

Much of the interference encountered affected the APGs and the peripheral operator maintenance and monitoring computers associated with the Mode S. The prime source of the RFI is from the primary radar. Additional problems began to arise towards the end of the integration effort at St. Albans that appear to be interference related. It was ascertained that an ultrahigh frequency (UHF) television station was granted approval and proceeded to transmit within 1,000 feet of the radar facility in this time frame. The relative power of this station's signal was low however in comparison to numerous other television and radio stations, cellular phone and pager systems, that are transmitting on the same mountaintop as the radar, as well as those located on an adjacent mountaintop 1 to 2 miles away. The highest level interference signal is most likely coming from the frequency modulation (FM) radio station transmitter, which is within 100 to 200 feet of the radar facility. The effects of these interference signals may cause the site to require additional shielding around the Mode S system. It should be of concern to the FAA that other transmitting RF sources will have an effect on newer generation radar systems that are highly computer/digitally oriented, with numerous interfaces to external computer/digital equipment. This may be especially of concern with commercial off-the-shelf (COTS) radar systems that may not have been designed to withstand levels of electromagnetic interference (EMI)/RFI required of the Mode S. The frequency management function of the agency needs to expand its focus beyond interference issues at the RF link level and also be concerned with the effects of RFI on computer/digital radar and communications equipment within the radar facilities.

5.4.5 Increasing PRF and Narrowing of Beamwidth to Increase Detection and Reliability.

One of the advantages of the Mode S systems is that it provides improved accuracy at a much reduced PRF. To achieve a high level of detection, though, there must be at least a minimum number of replies received from an aircraft each beam dwell. The Mode S is optimized to receive up to six replies/beam dwell for ATCRBS transponders, as opposed to up to 50 replies in Air Traffic Control Beacon Interrogator (ATCBI) mode of operation. For weak transponders, though, this can cause detection problems because of the limited number of replies received. ACT-310 is currently testing and plans to implement a change in the effective beamwidth utilized by the Mode S. The plan is to decrease the antenna beamwidth from 3.6° to 2.4° to minimize the sum channel antenna pattern rolloff effects. In order to compensate for the narrow beamwidth, an increase to the all-call PRF will be implemented to maintain a minimum of six ATCRBS replies per beam dwell. This will increase the probability of detection on the weaker targets, lessen the occurrence of code swaps, increase accuracy on Mode S targets, and reduce FRUIT. The net effect of doing this is a reduction of Mode S channel time for discrete transactions. This will not be a problem until a significant data link loading requirement is needed.

5.4.6 Maintainability Issues.

5.4.6.1 RMS Issues.

The enroute build of Mode S software implements the latest interface requirements for future integration with the MPS. Unfortunately, the amount of data that this provides to a user is both redundant and overwhelming. Even after a number of modifications to reduce the data, and the

ability to filter data, it is still very difficult to evaluate problems as they arise within the system. The RMS requirements of the MPS may need to be reevaluated in order to allow for a more practical and useable data exchange with the radar site. There is also a need to report out through the RMS interfaces Mode S Maintenance Input/Output (I/O) Processor (MIOP) messages, which provide much more specific detail when faults occur. This functionality is slated to be incorporated in the TU0x release and national upgrade.

6. OPERATIONAL EVALUATION AT KEY SITE.

The selected key site for the Mode S enroute operational evaluation was the St. Albans, Vermont, long-range radar. The facility is equipped with an FPS-68 ARSR and a CD-2. The facility provides surveillance coverage to the Boston ARTCC, located in Nashua, New Hampshire.

6.1 TEST OBJECTIVES.

a. Objective 1: To verify that the full-up Mode S system configuration is capable of providing appropriate surveillance coverage of designated enroute airspace.

b. Objective 2: To verify that the Area Control Computer Complex (ACCC) (HOST) processing systems, along with the Mode S/ARSR-2 subsystems, provide appropriate ATC services to specialists to control participating aircraft in surveillance coverage and for detection of violations of separation standards.

6.2 CONTROLLER SCRIPTS AT ARTCC.

6.2.1 Test Description.

The purpose of this test is to ensure no degradation of NAS functionality has occurred with Mode S operating on line. The air traffic controller operational evaluation procedure contained 14 different actions to ensure that targets could be correctly tracked; altitude data could be received and modified; beacon codes were received and could be changed; suppression of alert status; and ability to display all weather levels. For the initial air traffic controller operational evaluation periods, the sensor at St. Albans was set for Mode S mode and the radar was pulled out of NAS. A Planned Video Display (PVD) in the ARTCC then received ATCRBS and Mode S target reports for evaluation in DARC mode of operation. Operationally, air traffic (AT) was controlled by adjacent radars and by the HOST.

The following is a list of all the functions performed:

a. Start a track on a Mode S-equipped aircraft.

b. Drop a track on a Mode S-equipped aircraft.

c. Offset direction/leader length on a Mode S-equipped aircraft.

d. Force a Data Block on a Mode S-equipped aircraft.

e. Point out a Data Block on a Mode S-equipped aircraft.

f. Request/suppress Data Block on a Mode S-equipped aircraft.

g. Enter assigned altitude on a Mode S-equipped aircraft.

h. Enter reported altitude on a Mode S-equipped aircraft.

i. Enter interim altitude on a Mode S-equipped aircraft.

j. Insert/delete beacon codes (up to 9 codes of Mode S aircraft).

k. Request discrete code on a Mode S-equipped aircraft.

l. Modify code on a Mode S-equipped aircraft.

m. Request a Mode S-equipped aircraft to: squawk ident, squawk standby, change beacon code.

n. While in Mode S mode, display all levels of weather intensity.

6.2.2 Test Results.

The controller evaluation procedure produced no anomalies with regard to the Mode S. There were two abnormal situations noted during a 2-day period, but they both were concluded to be DARC anomalies. The first problem relates to at least three tracks that did not show Mode C data on the DARC display. The tracks were verified at both the radar site and on a HOST display to have Mode C data. The second problem was detected when two separate tracks being displayed by the DARC lagged the actual radar (transponder) target by at least 5 miles. In NAS, on a HOST display, they were tracked and corresponded with their respective radar targets. Both of these issues are being tracked as DARC problems.

6.3 CONTROLLER OPERATIONAL EVALUATION.

The Mode S at St. Albans was placed in Operational Readiness Demonstration (ORD) status on July 24, 1996. The controllers at Boston ARTCC have been utilizing the Mode S since that time. The system has been providing appropriate surveillance coverage of its designated enroute airspace. The Mode S, along with the HOST/DARC, is also providing the ATC services to specialists to control participating aircraft in surveillance coverage and for detection of violations of separation of standards.

The only anomalies thus far have been due to Mode S transponders, which are operating outside of certification limits. The predominant condition noted is that transponder irregularities will cause aircraft to be tracked and reported as two different tracks because of differences in its Mode 3/A reporting in Mode S replies and ATCRBS replies. These differences are typically only one or two bits off. The reason this occurs is because of the "Terra" algorithm implemented by the Mode S to insure proper detection of a particular model of ATCRBS transponders. To insure proper detection, the Mode S must interrogate with a "classic" ATCRBS interrogation

along with Mode S interrogation. Mode S transponders thus become tracked as both ATCRBS and Mode S tracks, and are merged at dissemination. If the Mode 3/A codes differ, there is no way of accurately knowing that they are not actually two different aircraft. The reason the transponders are acting as such has not been resolved, but there are a few possible reasons and include: (1) out of tolerance pulse characteristics of the ATCRBS reply; (2) problems in the digital signal processing within the transponder; or (3) the transponder is not properly signaling the Mode S that its Mode 3/A code has changed. Since the Mode S only requests the Mode 3/A code upon acquisition of the track, it does not request it again unless the transponder signals the Mode S that it has changed. Further investigation is needed in identifying and correcting the transponders.

6.4 KEY SITE SYSTEM PERFORMANCE.

6.4.1 Baseline Optimization.

The power, STC, and antenna tilt were all baseline when the Mode S was flight checked and commissioned in IBI. The power at the input of the antenna is set to 340 W (Directional)/810 W (SLS). The STC is set to 48 dB and the antenna tilt is set to 0°. To increase detection of the ATCRBS targets, the ATCRBS and auxiliary (AUX) receiver thresholds were both lowered 3 dB to -82 dBm.

6.4.2 Performance Characteristics.

Performance data from St. Albans has been collected at periodic intervals since the system transitioned to ORD status in July. One of the recommendations made in the quick-look report was to try to increase detection of low flying and weak fringe targets. This was to be achieved by narrowing the effective beamwidth of the Mode S from 3.6° to 2.4°. In addition, the effective All-Call interrogation rate was increased to maintain the normal six replies per target within each beam dwell. This was performed, and a difference can be seen in the surveillance Pd. Tables 6.4.2-1 through 6.4.2-5 summarize the performance of the system over the 3-month period after the start of operational usage. The totals from the tests conducted at the Technical Center are provided for comparison. Note on the surveillance analysis statistics that, after the beamwidth reduction change was implemented, there is over a 1-percent increase in detection for both Mode S and ATCRBS targets. The slight decrease in the validity and confidence figures is ironically due to the fact that by increasing detection, the system is now picking up additional fringe targets that were previously not detected enough to form a track and are now being picked up. Thus, the narrowing of the beam increases and improves a given envelope of coverage, but fringe conditions will always exist.

Though the Pd may seem lower in relation to the performance figures from the Technical Center, St. Albans is located in a mountainous coverage area. The surveillance data presented is unfiltered, so targets from out at 255 nmi and down to the low-lying commercial airports, Burlington, Vermont, and Montreal, Canada, both within 60 nmi, are included. A majority of the improved detection was achieved in these fringe areas.

TABLE 6.4.2-1. ST. ALBANS, SURVEILLANCE ANALYSIS

		Beacon Pd		Code Validity		Code Confidence		Altitude Validity		Altitude Confidence	
		ATCRBS	Mode S	ATCRBS	Mode S	ATCRBS	Mode S	ATCRBS	Mode S	ATCRBS	Mode S
3.6 Beamwidth	7/24a	96.81	97.97	99.61	100.00	99.83	100.00	99.32	99.71	99.24	100.00
	7/24b	96.81	97.97	99.61	100.00	99.83	100.00	99.32	99.71	99.24	100.00
	10/08a	96.68	97.58	99.77	99.99	99.96	99.99	99.03	99.42	99.31	99.96
	10/08b	96.34	97.84	99.84	100.00	99.95	100.00	99.55	99.65	99.60	100.00
2.4 Beamwidth	12/05a	98.37	99.26	99.31	100.00	99.61	100.00	98.63	99.53	98.45	99.97
	12/05b	97.18	99.05	99.08	99.99	99.38	99.99	98.32	99.80	98.36	99.98
	12/09	97.59	99.27	99.35	99.99	99.59	99.99	98.36	99.73	98.49	99.97
3.6 Beamwidth		96.66	97.84	99.71	100.00	99.89	100.00	99.31	99.62	99.35	99.99
2.4 Beamwidth		97.71	99.19	99.25	99.99	99.53	99.99	98.44	99.69	98.43	99.97
FAATC		98.27	99.56	99.73	99.97	99.90	99.98	98.77	99.91	98.91	99.97

TABLE 6.4.2-2. ST. ALBANS, BEACON FALSE TARGET ANALYSIS

	Splits	Uplink Reflections	Downlink Reflections
7/24a	0.04	0.01	0.00
7/24b	0.01	0.01	0.00
10/08a	0.05	0.00	0.00
10/08b	0.02	0.00	0.01
10/09b	0.02	0.00	0.01
12/05b	0.02	0.02	0.00
TOTAL	0.03	0.01	0.00
FAATC	0.07	0.00	0.00

TABLE 6.4.2-3. ST. ALBANS, CONFLICT ANALYSIS

	Beacon Pd	Code Validity	Code Confidence	Altitude Validity	Altitude Confidence
7/24	96.77	97.16	98.53	97.1	95.66
10/08a	97.25	99.25	100	97.7	97.7
10/08b	97.21	99.23	100	98.28	98.28
10/09	94.23	95.24	94.25	93.87	93.28
12/05b	96.17	96.22	97.21	97.22	94.85
12/09	96.43	97.26	98.15	95.97	94.98
TOTALS	96.34	97.39	98.02	96.69	95.79
FAATC	98.54	99.53	99.82	98.74	98.78

TABLE 6.4.2-4. ST. ALBANS, MODE S FIXED TRANSPONDER ACCURACY

CPME 1272	Range Bias (ft.)		Range Jitter (ft.)		Azimuth Bias (deg.)		Azimuth Jitter (deg.)	
	ATCRBS	Mode S	ATCRBS	Mode S	ATCRBS	Mode S	ATCRBS	Mode S
7/24	154.2	132.7	24.9	9.7	-0.003	-0.008	0.012	0.026
10/08b	158.6	133.2	25.4	10.8	0.003	0.003	0.010	0.015
10/08a	30.1	12.9	25.4	6.7	-0.005	-0.006	0.012	0.014
TOTALS	114.3	92.9	25.2	9.1	-0.002	-0.004	0.011	0.018
FAATC	38.9	43.4	16.2	10.2	0.066	0.074	0.033	0.041

TABLE 6.4.2-5. ST. ALBANS, 9-POINT ANALYSIS

	Range Jitter (ft.)		Azimuth Jitter (deg.)	
	ATCRBS	Mode S	ATCRBS	Mode S
7/24b	99.9	72.6	0.036	0.0281
10/08a	93.4	94.4	0.0327	0.0266
10/08b	74.3	75.5	0.0287	0.0273
TOTALS	89.2	80.8	0.032	0.027
FAATC	54.5	53.7	0.045	0.044

6.4.3 Conclusions.

Both of the objectives were met during this test period. There is a continuing problem at the St. Albans facility with RFI interference, and ACT-310, AOS-510, and AND-450 are continuing their efforts to identify and harden any area within the Mode S to eliminate the occasional alarms that are occurring.

7. SUMMARY OF CONCLUSIONS.

This Mode Select Beacon System (Mode S) enroute Operational Test and Evaluation (OT&E) report has provided an evaluation of the enroute single face configuration of the Mode S system and has identified issues that may impact integration into some enroute facilities. Appendix A contains a summary of issues resulting from the Mode S enroute OT&E and appendix B addresses all of the performance and integration requirements called out in the Test Verification Requirements Traceability Matrix (TVRTM).

The test results indicate that in the area of surveillance performance both quality and accuracy of the data provided to air traffic control (ATC) has improved over currently fielded systems. As noted with the Mode S terminal OT&E, these results were expected due to the improved performance achievable with the monopulse reply processing and discrete interrogation functions within the Mode S. Detection of weak/fringe targets has been further improved by the narrowing of the beamwidth and slight increase in the pulse repetition frequency (PRF), especially in mountainous terrain. With no data link requirements in place for the enroute systems at this time, this can be done without sacrificing any surveillance capacity loading.

Mode S capacity and throughput capabilities will be less than the specified 700 aircraft until the 3 x 2,400 baud transmission line requirement of the Direct Access Radar Computer (DARC) is removed. This should not be a near-term issue at any of the operational enroute Mode S sites slated for deployment since this is currently a limitation affecting all enroute radar feeds to Air Route Traffic Control Centers (ARTCCs). The Mode S has successfully been tested at its full capacity with 3 x 9,600 bits per second (bps) lines and does meet the 1.5-second throughput requirement (from antenna boresight to modem input).

Air traffic controllers at the Boston and Denver ARTCCs have not experienced any major problems, with respect to Mode S, while controlling air traffic with the surveillance data being provided by the Mode S. The Mode S has uncovered a number of different bad transponder conditions. These include Mode S transponders with illegal Mode S identities (IDs) which result in 0000 Air Traffic Control Radar Beacon System (ATCRBS) code reporting, nonsuppressing ATCRBS transponders which reply to Mode S-only interrogations, and Mode S transponders that report conflicting Mode 3/A or Mode C data in Mode S versus ATCRBS replies.

Another long-term issue with respect to bad transponders is the "Terra" transponder problem. The Mode S currently has to dual interrogate and track Mode S transponders, both as Mode S and as ATCRBS. Fortunately, for the near term, the ability of the enroute Mode S to overlap Mode S and ATCRBS all-call periods and the fact that many Mode S transponders in use were built to the old Minimum Operational Performance Standards (MOPS), which allowed for up to 128 microseconds (μsecs) suppression, allow the system to remain within its capacity limits.

However, for the long term, the newer Mode S transponder MOPS requires the transponders to unsuppress at 45 μsecs. This means all Mode S transponders will have to be dual tracked. With a 255 nautical miles (nmi) radial coverage and a greater than 2:1 majority of Mode S transponders in the sky, the effective target capacity of the Mode S will be limited to less than 420 targets. The need for this mode of operation will have to be resolved by either assuming that all "Terra" type transponders are no longer a threat or make major modifications to Mode S' tracking algorithms to perform Mode S/ATCRBS track merging at the report level instead of the surveillance track level.

The biggest problem that may arise in the integration of the remaining enroute Mode S facilities will be radio frequency interference (RFI) on the Mode S and its peripheral computer and communication subsystems. These issues will have to be dealt with on a site-by-site basis. It should be of concern to the Federal Aviation Administration (FAA) that other transmitting radio frequency (RF) sources in close proximity of the radar facilities will have an effect on newer generation radar systems that are highly computer oriented, with numerous interfaces to additional computer equipment. This may be especially of concern with commercial off-the-shelf (COTS) radar systems that may not have been designed to withstand levels of electromagnetic interference (EMI)/RFI required of the Mode S. The frequency management function within the agency needs to expand its focus beyond interference issues at the RF link level and also be concerned with the effects of RFI on the computer/digital subsystems within radar systems, and the associated peripheral computer and communications equipment within the radar facilities.

This baseline of software, along with any maintenance release, is being reintegrated with the terminal baseline and ported to an upgraded processor platform. This upgrade will entail replacing the core 68020 computer processing units (CPUs) and the Maintenance Input/Output (I/O) Processors (MIOPs) in the Data Processing Subsystem (DPS) with 68040 CPUs. This enhanced functionality will expand the systems' processing capability and allow new functions to be added to the systems, such as dynamic reflector processing. This is the basis by which the national upgrade will bring the remaining enroute Mode S up into full operational mode and provide a common software baseline for both terminal and enroute configuration.

8. RECOMMENDATIONS.

Additional work and evaluation will continue to be done at the St. Albans facility to better isolate the Mode Select Beacon System (Mode S) from radio frequency interference (RFI). The effects on the system vary day-to-day and week-to-week and will occasionally force the system into Air Traffic Control Beacon Interrogator (ATCBI) mode. Grounding may be one area that can be improved and may reduce the system's susceptibility to interference. In addition, the following recommendations are suggested prior to full national deployment.

a. ***Search Real Time Quality Control (RTQC) message processing within the Mode S.*** A number of changes need to be incorporated into the Mode S to guarantee properly formatted search RTQC messages are always sent to the Air Route Traffic Control Center (ARTCC). A site adaptable parameter (SAP) should allow the user to select whether the Mode S should generate synthetic search RTQC messages. At beacon-only sites, this would be required. At collocated Common Digitizer (CD)-2 site, if the Mode S generates the messages, it should

intercept the search RTQC generated by the CD-2. Should the CD-2 not generate a message, or generate one at an incorrect position, the Mode S should then set the search RTQC alarm bit in the status message if the CD-2 has not already done so. Problems within the CD-2 should be reflected in the status message and through the CD-2's Remote Maintenance Subsystem (RMS) interface. The search RTQC should in no way be allowed to compromise the ability of the site to provide beacon data while the site is in Mode S mode of operation. (PTR: 10286329V and 10286328V)

b. ***Increasing pulse repetition frequency (PRF) and narrowing of beamwidth to increase detection and reliability.*** One of the advantages of the Mode S system is that it provides improved accuracy at a much reduced PRF. To achieve a high level of detection, though, there must be at least a minimum number of replies received from an aircraft each beam dwell. The Mode S is optimized to receive up to six replies/beam dwell for Air Traffic Control Radar Beacon System (ATCRBS) transponders, as opposed to up to 50 replies in ATCBI mode of operation. For weak transponders, though, this can cause detection problems because of the limited number of replies received. ACT-310 is currently testing and plans to implement a change in the effective beamwidth utilized by the Mode S. The plan is to decrease the antenna receive beamwidth from 3.6° to 2.4° and increase the all-call PRF to maintain a minimum of six ATCRBS replies per beam dwell. This will increase the probability of detection on the weaker targets, lessen the occurrence of code swaps, increase accuracy on Mode S targets, and reduce FRUIT. The net effect of doing this is a reduction of Mode S channel time for discrete transactions which are partially used to provide data link functionality to the aircraft. This 40-percent reduction in Mode S channel time will not be a problem until a significant data link loading requirement is needed.

c. ***Status message processing within the Mode S needs to be modified.*** The current implementation of status message processing has the Mode S controlling the five beacon related bits. Two of the bits indicate on-line and standby beacon channel alarms, where a red condition on the standby channel will set the standby beacon alarm and a yellow condition on the on-line channel will set the on-line beacon alarm. Feedback from key site testing has resulted in a request to change the definition of the on-line channel alarm to be a red condition as is done on the standby channel. This criteria would eliminate incorrect interpretation of the operational standing of the Mode S at the System Maintenance Monitor Console (SMMC) located at the ARTCC. This will require both a National Change Proposal (NCP) and a change to the Mode S/CD-2 Interface Control Document (ICD). (PTR: 10286331)

A second change being recommended to the status message is to have the Mode S set the buffer overload alarm bit whenever the system enters a throttling processing mode. This would mean that either the CD-2 or the Mode S could set this bit whenever either system is under a buffer overload condition. (PTR: 10286331)

d. ***Surveillance dissemination enhancement to mimic functionality of Clock Box.*** The functions of the Clock Box should be provided by the Mode S. The Mode S was designed to provide surveillance and data link services to multiple facilities, up to six each. The Mode S software can be modified to provide the proper three letter site identity (ID) and modem channel ID information in the surveillance data stream. This would eliminate the need for the additional

single-point-of-failure Clock Box in the critical data path and not compromise the system's ability to monitor its surveillance output interfaces. The Clock Box can remain in the CD-2 output path between the CD-2 junction box and the Mode S surveillance data selector (SDS) switch in the communications junction box. (PTR: 10286328V)

e. ***Inclusion of all SAR214D and SAR214E fix packages.*** Inclusion of these updates would provide multiple advantages. First, there are changes implemented to handle Mode S transponders that transmit on the ground. Corrections have been made to correct anomalies in the "Terra" algorithm, as well as other surveillance enhancements to improve detection and reduce false targets. Second, it provides a baseline for which a comparison can be made directly with the first implementation of the MPU40 upgrade. (PTR: 10286330V)

f. ***Remote Terminal (RT) enhancement to provide system resets.*** Due to the limited amount of space available at the ARTCC, there is only enough room for one Mode S monitor/control terminal. Since the Mode S has not yet been integrated into the Maintenance Processor Subsystem (MPS), the System Engineers (SEs) have no ability to remotely reset the Mode S. Additional functionality could be implemented into the RT to provide a pull-down menu to allow for individual channel initializations or a total system master reset. (PTR: 10286326V)

g. ***SAP controllable selection of default primary point of control (RT, Local Terminal (LT), or Mode S Interim Monitoring and Control Terminal (MSIMC)).*** This would allow the RT to be replaced with the MSMIC as an alternative interim solution to the above-mentioned problem. It also allows the site technician to temporarily change the default control point to the LT during periods of maintenance. (PTR: 10286327V)

9. DEFINITION OF TERMS AND ACRONYMS.

A	ATCRBS Targets (in tables)
AAS	Advanced Automation System
ACCC	Area Control Computer Complex
ACP	Azimuth Change Pulse
APG	Azimuth Pulse Generator
ARIES	Aircraft Reply and Interference Environment Simulator
ARSR	Air Route Surveillance Radar
ARTCC	Air Route Traffic Control Center
AT	Air Traffic
ATC	Air Traffic Control
ATCBI	Air Traffic Control Beacon Interrogator
ATCRBS	Air Traffic Control Radar Beacon System
Au	Azimuth Unit
AUX	Auxiliary

Azimuth Splits	Azimuth splits occur when beacon replies of a target are interrupted and two targets are declared.
BFTA	Beacon False Target Analysis
BFTS	Beacon False Target Summary
BIT	Built-In Test
Blip/scan ratio (Probability of Detection)	The ratio of blips (the number of times a target was detected) to scans (the number of times the target should have been detected) is expressed as a percentage. The blip/scan ratio is an important figure for evaluating radar performance. For example, if the blip/scan value falls to 60 percent, the probability is greater that tracks will go into the coast mode much more frequently.
bps	bits per second
CD	Common Digitizer
CDC	Computer Display Channel
Ch	Channel
CID	Communications Interface Driver
Conflict	When two or more targets are within 2 nautical miles (nmi) and 4° of each other.
COTS	Commercial Off-the-Shelf
CP	Capacity Scenario (in tables)
CPME	Calibration and Performance Monitoring Equipment
CPU	Computer Processing Unit
cw	Clockwise
DARC	Direct Access Radar Computer
DART	Data Analysis and Reduction Tool
dB	decibel
dBm	decibel below the level of a milliwatt. The loss in decibels is 10 times the logarithm of the power ratio, where the reference power level is 1 milliwatt.
DCC	Display Channel Complex
DE	Data Extraction
DPS	Data Processing Subsystem
DR	Data Reduction
EMI	Electromagnetic Interference
FAA	Federal Aviation Administration

FAATC	Federal Aviation Administration Technical Center
False Target Reports	Any discrete beacon code report determined by software analysis to be split in azimuth, split in range, or a reflected target report.
FGAR	Fixed Ground Antenna Radome
FIT	Fault Isolation Test
FM	Frequency Modulation
FPS	Fixed Position Search (Radar)
FQT	Formal Qualification Test
FRUIT	False Replies Unsynchronized In Time. Non synchronous replies, such as those caused by interrogation of the transponders by other interrogators, are called FRUIT.
FRUIT Rate	FRUIT is transponder replies to interrogators other than the interrogator of interest. FRUIT replies appear asynchronous to the interrogator of interest. FRUIT levels are given in the following table:

Level	ATCRBS	Mode S
Moderate	4,000	50
Intermediate	20,000	100
Heavy	40,000	200

Garble	The sensor condition where replies from different targets overlap.
Garbled Replies	When two aircraft are located at approximately the same slant range and azimuth, their beacon replies can overlap. Overlapped replies that cannot be separated in time are processed as garbled replies.
HF	Heavy FRUIT (in tables)
HOST	Computer System (not an acronym)
I/O	Input/Output
IBI	Interim Beacon Initiative
ICD	Interface Control Document
ID	Identity
IRD	Interface Requirements Document
ISLS	Improved Side-Lobe Suppression
k	kilos
kbps	kilobits per second
LMT	Local Maintenance Terminal

LT	Local Terminal
LU	Logical Unit
μsec	microsecond
M	Mixed Targets (in tables)
MF	Moderate FRUIT (in tables)
MIOP	Maintenance Input/Output Processor
Mode S	Mode Select Beacon System
MOPS	Minimum Operational Performance Standards
MPS	Maintenance Processor Subsystem
MSIMC	Mode S Interim Monitoring and Control Terminal
N/A	Not Applicable
NADIF	NAFEC Dipole Feed
NAFEC	National Aviation Facilities Experimental Center
NAS	National Airspace System
NCP	National Change Proposal
NF	No FRUIT (in tables)
nmi	nautical mile
ORD	Operational Readiness Demonstration
Orientation	Orientation of an azimuthal or back-lobe reflector is the angle measured from true north to the face of the reflecting surface. Orientation of a downlink reflector is the angle measured between the plane of the reflector and a line perpendicular to the antenna tower.
ORR	Online Radar Recording
OT&E	Operational Test and Evaluation
PAMRI	Peripheral Adapter Module Replacement Item
Pd	Probability of Detection (see Blip/Scan Ratio)
PEA	Permanent Echo Accuracy
Pfa	Probability of False Alarm
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
PTR	Program Technical Report
PVD	Planned Video Display
QPK	Parker, Colorado

Radar Reinforced	The radar reinforced value is the ratio of the number of beacon messages with the reinforced bit set to the total number of beacon messages received, expressed as a percentage.
RBAT	Radar Beacon Analysis Tool
Reflections	A discrete beacon code report within one scan interval of a second report determined to be the true report. The true report is considered to be the report from the target that was present during previous scans.
RF	Radio Frequency
RFI	Radio Frequency Interference
RIT	Radar Intelligence Tool
RMMS	Remote Maintenance Monitoring System
rms	root mean square
RMS	Remote Maintenance Subsystem
RT	Remote Terminal
RTADS	Real Time Aircraft Display System
RTQC	Real Time Quality Control
Ru	Range Unit
RW	Real World Scenario (in tables)
S	Mode S Targets (in tables)
SA	Surveillance Analysis
SAMF	Surveillance Advanced Message Formats
SAP	Site Adaptable Parameter
SDQ	Sensor Design Qualification
SDS	Surveillance Data Selector
SE	System Engineer
sec	second
SLS	Side-Lobe Suppression
SMMC	System Maintenance Monitor Console
STC	Sensitivity Timing Control
Std-Dev	Standard Deviation
TIS	Traffic Information Service
Track Swap	This is a condition where two or more targets come into close proximity (usually a conflict), and this causes a misassignment at least one target identity (ID) for the duration of that track.

TVRTM	Test Verification Requirements Traceability Matrix
UHF	Ultrahigh Frequency

APPENDIX A

MODE S ENROUTE OT&E ISSUES MATRIX

MODE S ENROUTE OT&E ISSUES MATRIX

#	LEVEL	ISSUE	PROPOSED SOLUTION
1	Moderate	Corruption of Azimuth Pulse Generator (APG) data from azimuth encoders.	The current fix is to install an APG conditioning circuit. The long-term fix should be to replace the APG encoders with ones that can properly operate in the enroute rotary joint environment.
2	Moderate	Radio frequency interference (RFI) on system, peripheral computer, and communications subsystems	This will be a site-by-site local issue. Proper grounding and electromagnetic interference (EMI)/RFI provisions need to be evaluated and corrected where required.
3	Minor	Capacity loading limited with current National Airspace System (NAS) limitations on modem transmission speeds.	System will be limited until the Direct Access Radar Computer (DARC) limitations are removed.
4	Minor	Throughput exceeds requirement limits due to current NAS limitations on modem transmission speeds.	System will be limited until the DARC limitations are removed.
5	Moderate	Capacity limitations due to the current requirement to process illegal Air Traffic Control Radar Beacon System (ATCRBS) transponders (i.e., "Terra" type transponders).	The current fix for this problem is only a temporary remedy. Higher density facilities and newer generation data link equipped transponders will overload the current capacity of the system. Possible solutions: Eliminate illegal transponders, modify Mode Select Beacon System (Mode S) to merge ATCRBS and Mode S tracks at the report level, or double the target capacity of Mode S (700→1400 beacon targets).
6	Moderate	Incompatible interface between Mode S surveillance output and Clock Box.	Modify Mode S software to perform functions of the Clock Box or reengineer the input interface to meet RS-232 or EIA-530 standards. (Program Technical Report (PTR) #10286328V)

#	LEVEL	ISSUE	PROPOSED SOLUTION
7	Moderate	Mode S does not perform any post-processing on Search Real Time Quality Control (RTQC) messages from Common Digitizer (CD)-2.	Modify Mode S software to process Search RTQC messages in the same fashion as the CD-2's modem adapter, as well as guarantee that the Search RTQC is always properly generated in Mode S mode of operation. The alternative is to modify NAS at the Air Route Traffic Control Center (ARTCC) to not mark the site out of service when a problem arises with the CD-2 and the site is in full Mode S mode of operation. (PTR #10286329V)
8	Minor	Mode S does not disseminate multiple status messages received from CD-2.	Modify Mode S software to disseminate all status messages received from the CD-2. (PTR #10286331V)
9	Major	Mode S does not disseminate a synthetic Search RTQC in Beacon-Only mode.	Modify Mode S to provide Search RTQC. Alternative, modify NAS to ignore missing Search RTQC. (PTR #10286329V)
10	Moderate	Inability to remotely reset the Mode S from the Remote Terminal (RT).	Due to space limitations at the ARTCC, the RT is the only Remote Maintenance Subsystem (RMS) interface to the Mode S. Until the Maintenance Processor Subsystem (MPS) is able to operate with a Mode S, the RT should provide system reset capabilities for the System Engineers (SE). (PTR #10286326V)
11	Minor	Low Probability of Detection (Pd) performance in low altitude and fringe coverage areas.	Modification of Mode S site adaptable parameters to narrow the beamwidth and increase the effective all-call Pulse Repetition Frequency (PRF) would increase detection and reliability of data. Would have to be reevaluated if a sizable data link load is introduced into the environment.
12	Moderate	Red on-line Mode S channel as a result of an injected fault condition.	Mode S Built-In Test (BIT)/Fault Isolation Test (FIT) processing between the Data Processing Subsystem (DPS) and Interrogator needs to be corrected. (PTR #8296244V)
13	Minor	Calibration parameters can cause the Calibration and Performance Monitoring Equipment (CPME) to be overdriven and blank out during the calibration process.	Need to change the default calibration interrogation Pulse Repetition Interval (PRI) as a function of scan rate to ensure the CPME is operating within its specified limits.

APPENDIX B

TEST VERIFICATION REQUIREMENTS TRACEABILITY MATRIX (TVRTM)

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
1100	Verify Mode S reduces false target reports that result from multipath effects. (AES OT&E Requirement 2.4)	P	FAATC	T	4.7	P	
1100	Verify that NAS shall provide air traffic control services to the user/specialist to control participating aircraft in/out surveillance coverage.	I	Key Site	T	6.2	P	
1110	Verify Mode S reduces garble by use of monopulse beacon operations. (AES OT&E Requirement 2.5)	P	FAATC	T	4.9	P	
1120	Verify Mode S reduces garble by use of Mode S aircraft interrogation capability. (AES OT&E Requirement 2.5)	P	FAATC	T	4.4	P	
1150	Verify that NAS shall provide air traffic control services to the specialists for the detection of violations of operational standards coverage.	I	Key Site	T	6.2	P	
1200	Mode S shall detect all transponder equipped aircraft targets (within the detection envelope specified in 3.2.1.1.6.2.1) with a reply probability of detection (Pd) greater than 0.99, with a probability of constant false alarm (Pfa) less than 10^{-6} in any one second, when received reply power is greater than –76 decibels below the level of a milliwatt (dBm) referenced to the sensor RF port in the absence of signal (RF) interference. (3.2.1.1.6.2.2)	P	FAATC	T	4.2	P	
1210	Mode S shall detect all transponder equipped aircraft targets (within the detection envelope specified in 3.2.1.1.6.2.1) with a sensor-only range error not exceeding + or – 30 feet bias (including long term drift) and 25 feet rms jitter for Mode S reports. (3.2.1.1.6.2.3)	P	FAATC	T	4.8	F	Fails bias requirement by less than 1 ru. Added bias attributed to change in environmental conditions on the CPME.
1220	Mode S shall detect all transponder equipped aircraft targets (within the detection envelope specified in 3.2.1.1.6.2.1) with a sensor-only range	P	FAATC	T	4.8	F	Fails bias requirement by less than 1 ru. Added bias attributed to change in environmental conditions on

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
	error not exceeding + or – 30 feet bias (including long term drift) and 25 feet rms jitter for ATCRBS reports. (3.2.1.1.6.2.3)						the CPME.
1230	Mode S shall detect all transponder equipped aircraft targets (within the detection envelope specified in 3.2.1.1.6.2.1 and using the government furnished five-foot open array antenna) with a long term combined sensor plus antenna azimuth accuracy for Mode S reports, which shall not exceed: a. Bias of + or – 0.033 degrees for elevation angles less than 2 degrees (exclusive of antenna windload but including long term drift); (3.2.1.1.6.2.4.a.) b. Jitter less than 0.060 degrees, 1 Sigma for elevation angles less than 20 degrees. (3.2.1.1.6.2.4.b.)	P	FAATC	T	4.8	F	Fails bias requirement by about 1 au. Problem attributed to mechanical shifts in the rotary joint with respect to the antenna pedestal.
1240	Mode S shall detect all transponder equipped aircraft targets (within the detection envelope specified in 3.2.1.1.6.2.1 and using the government furnished five-foot open array antenna) with a long term combined sensor plus antenna azimuth accuracy for ATCRBS reports, which shall not exceed: a. Bias of + or – 0.033 degrees for elevation angles less than 2 degrees (exclusive of antenna windload but including long term drift); (3.2.1.1.6.2.4.a.) b. Jitter less than 0.060 degrees, 1 Sigma for elevation angles less than 20 degrees. (3.2.1.1.6.2.4.b.)	P	FAATC	T	4.8	F	Fails bias requirement by about 1 au. Problem attributed to mechanical shifts in the rotary joint with respect to the antenna pedestal.
1250	Mode S shall detect all transponder equipped aircraft targets (within the detection envelope specified in 3.2.1.1.6.2.1) at a rate identical to that of the associated primary radar. (3.2.1.1.6.2.5)	P	FAATC	T	4.6	P	

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
1260	Mode S shall detect all transponder equipped aircraft targets (within the detection envelope specified in 3.2.1.1.6.2.1) at a rate of 12 seconds, +1.33 or –1.09 seconds for stand-alone Mode S sensors. (3.2.1.1.6.2.5)	P	FAATC	T	4.6	P	
1260	Verify that NAS shall provide positional data of all detected cooperative aircraft (ATCRBS beacon equipped) within enroute airspace.	I	FAATC	T	5.2	P	
1275	Verify that NAS shall provide identification of all detected cooperative aircraft (ATCRBS beacon equipped) within enroute airspace.	I	FAATC	T	5.2	P	
1290	Verify that NAS shall provide positional data of all detected cooperative aircraft (Mode S beacon equipped) within enroute airspace.	I	FAATC	T	5.2	P	
1300	The Mode S sensor shall generate an ATCRBS/Mode S All Call interrogation type. (3.2.1.1.6.2.6)	P	FAATC	T	5.	P	
1305	Verify that NAS shall provide identification of all detected cooperative aircraft (Mode S beacon equipped) within enroute airspace.	I	FAATC	T	5.2	P	
1310	The Mode S sensor shall generate an ATCRBS Only All Call interrogation type. (3.2.1.1.6.2.6)	P	FAATC	T	---	P	Validated during terminal OT&E.
1320	The Mode S sensor shall generate an ATCRBS interrogation type. (3.2.1.1.6.2.6)	P	FAATC	T	4.6	P	
1320	Verify that NAS shall provide positional data of all detected cooperative aircraft (ATCRBS beacon equipped) within sovereignty airspace.	I	FAATC	T	5.2	P	
1330	The Mode S sensor shall generate a Mode S All Call interrogation type. (3.2.1.1.6.2.6)	P	FAATC	T	4.6	P	Validated during terminal OT&E.
1335	Verify that NAS shall provide identification of all detected cooperative aircraft (ATCRBS beacon equipped) within sovereignty airspace.	I	FAATC	T	5.2	P	

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
1340	The Mode S sensor shall generate a Mode S Roll Call interrogation type. (3.2.1.1.6.2.6)	P	FAATC	T	4.6	P	
1350	The Mode S sensor shall be capable of interlacing patterns of the beacon modes (2, 3A, B, C, D) in the ATCRBS interrogations. (3.2.1.1.6.1.2.b.)	P	FAATC	T	---	P	Validated during terminal OT&E.
1350	Verify that NAS shall provide positional data of all detected cooperative aircraft (Mode S beacon equipped) within sovereignty airspace.	I	FAATC	T	5.2	P	Same as 1290 with respect to beacon targets.
1365	Verify that NAS shall provide identification of all detected cooperative aircraft (Mode S beacon equipped) within sovereignty airspace.	I	FAATC	T	5.2	P	Same as 1305 with respect to beacon targets.
1400	The Mode S sensor shall delay uplink data link messages no more than 1/16 of a scan period from the time of receipt until they are processed and available for delivery to discretely addressed Mode S transponder equipped aircraft. (3.2.1.1.6.2.9) (Additional processing as specified in 3.2.1.1.6.2.10 shall be accomplished, except when collocated with an ASR-9.)	P	Contractor Facility	T	4.5	P	Validated during DT&E testing, System Design Qualification Test #5 (SDQ5).
1410	The Mode S sensor shall delay downlink data link messages no more than 1/16 of a scan period from the time the message is received until it is available for transmission from the sensor to the destinations specified in Table 3.2.1.1.6.3-1. (3.2.1.1.6.2.9) (Additional processing as specified in 3.2.1.1.6.2.10 shall be accomplished, except when collocated with an ASR-9.)	P	Contractor Facility	T	4.5	P	Validated during DT&E testing, SDQ5.

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
1500	When sufficient time exists to complete a Mode S roll-call on all targets within a beam dwell, the Mode S sensor shall allocate the available time on the following priority basis: a. Surveillance and high priority standard length messages; b. High priority uplink extended length messages (ELM); c. Additional (lower priority) standard length messages; d. Uplink ELMs; e. Downlink ELMs. (3.2.1.1.6.1.5.a.)	P	FAATC	T	4.5	P	
1500	Verify that NAS shall provide traffic control services to the user/specialist to identify, monitor, and support the control of participating aircraft in/out surveillance coverage through the utilization of standard procedures and the capabilities defined in this section and in 3.2.1.2.3, 3.2.1.2.7, and 3.2.1.2.8.	I	Key Site	T	6.	P	
1510	Transactions not completed on an aircraft shall be placed on the next schedule, subject to the following priority basis: a. Surveillance and high priority standard length messages; b. High priority uplink extended length messages (ELM); c. Additional (lower priority) standard length messages; d. Uplink ELMs; e. Downlink ELMs. (3.2.1.1.6.1.5.a.)	P	FAATC	T	4.5	P	
1575	Verify that NAS shall provide specialist with information on aircraft entering the ADIZ/DEWIZ in accordance with 3.2.1.2.7.	I	---	D	---	---	Deferred.

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
1600	The Mode S sensor shall accept target replies and prepare output surveillance reports (selected entities from Table 3.2.1.1.6.3-1) subject to the following per scan capacities: a. Any mixture of 700 Mode S and ATCRBS beacon targets; b. 1000 primary radar target reports; c. Non-uniform beacon target distribution of: (1) 250 targets within a 90 degree quadrant; (2) 50 targets within an 11.25 degree sector for up to 4 consecutive sectors; (3) 32 targets within a 2.4 degree wedge. These surveillance target capacities shall be met simultaneously for a uniform range distribution of targets within 50 nmi using 2.4 degrees beamwidth and a 4.8 second scan rate. These conditions may occur consecutively in any order. (3.2.1.1.6.2.11)	P	FAATC	T	---	P	Validated during terminal OT&E.
1610	The Mode S sensor shall be capable of receiving or outputting data link messages for 700 Mode S equipped aircraft per scan. (3.2.1.1.6.2.12)	P	FAATC	T	4.5	P	
1620	The Mode S sensor shall be capable of receiving or outputting data link messages under following per scan target capacities: a. Any mixture of 700 Mode S and ATCRBS beacon targets; b. 1000 primary radar target reports; c. Non-uniform beacon target distribution of: (1) 250 targets within a 90 degree quadrant;	P	FAATC	T	4.5	P	

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
	(2) 50 targets within an 11.25 degree sector for up to 4 consecutive sectors; (3) 32 targets within a 2.4 degree wedge. (3.2.1.1.6.2.13.a.)						
1630	The Mode S sensor shall provide efficient data channel utilization under any data link scenario realizable within the channel time line. Demonstration of efficient data channel utilization shall be accomplished by simultaneously satisfying, within one scan, the requirements as summarized in the following data link peaking scenario:	P	FAATC	T	4.5	P	

Table 3.2.1.1.6.2.13-1 Data Link Peaking Scenario

Type of Peaking (Per Scan)		Number of Mode S Targets	Targets Receiving (N) Comm-As, where N =				Targets Transmitting (N) Comm-Bs, where N = (Note 4)				Targets Receiving Uplink ELMs (1)	Targets Receiving Downlink ELMs (1)
			1	2	4	8	1	2	3	4		
2.4 degree Wedge												
CASE I	(2)	12	4	0	5	3	3	2	1	1	1	0
CASE II	(5)	32	0	32	0	0	14	0	0	0	0	0
11.25 degree Sector	(3)	50	24	0	20	6	8	4	2	2	8	3
90 degree Quadrant		250	140	0	85	25	32	16	8	8	40	15

Note:
(1) 16 – Segment ELMs.
(2) 12 targets in 2.4 degree wedge for two consecutive wedges.
(3) 50 targets in 11.25 degree sectors for four consecutive sectors.
(4) Includes air-initiated COMM-B as follows:
    2.4 degree wedges: 5
    11.25 degree sector: 8
    90.0 degree quadrant: 30
    No more than one message per aircraft, for 700 aircraft, uniformly distributed in range.
(5) 32 targets in 2.4 degree wedge.

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
1640	Verify that total surveillance data response time shall not exceed 3.500 seconds for the ARSR-3 + Mode S sensor site configuration as shown in Table 3.2.1.2.7.1.1-1.	I	---	D	---	---	Deferred ARSR-3 configuration.
1660	Verify that total surveillance data response time shall not exceed 3.500 seconds for the ARSR-4 + Mode S sensor site configuration as shown in Table 3.2.1.2.7.1.1-1.	I	---	D	---	---	Deferred ARSR-4 configuration.
1680	Verify that total surveillance data response time shall not exceed 3.500 seconds for the Mode S Stand-alone sensor site configuration as shown in Table 3.2.1.2.7.1.1-1.	I	FAATC	T	5.4	F	This due to NAS 2400 bps communication limit. Under end state conditions, the system can successfully achieve this requirement.
1700	The Mode S sensor shall provide data link message storage for 4800 uplink messages. (3.2.1.1.6.2.14.a.)	P	Contractor Facility	T	4.5	P	Validated during DT&E testing, SDQ5.
1710	The Mode S sensor shall provide data link message storage for 1100 downlink messages. (3.2.1.1.6.2.14.b.)	P	Contractor Facility	T	4.5	P	Validated during DT&E testing, SDQ5.
1740	Verify that the surveillance data response time to the sensor site shall not exceed 1.500 seconds for the ARSR-3 + Mode S sensor site configuration as shown in Table 3.2.1.2.7.1.1-1.	I	---	D	---	---	Deferred ARSR-3 configuration.
1760	Verify that the surveillance data response time to the sensor site shall not exceed 1.500 seconds for the ARSR-4 + Mode S sensor site configuration as shown in Table 3.2.1.2.7.1.1-1.	I	---	D	---	---	Deferred ARSR-4 configuration.
1780	Verify that the surveillance data response time to the sensor site shall not exceed 1.500 seconds for the Mode S Stand-alone sensor site configuration as shown in Table 3.2.1.2.7.1.1-1.	I	FAATC	T	5.4	F	This due to NAS 2400 bps communication limit. Under end state conditions, the system can successfully achieve this requirement.
1800	The Mode S envelope for terminal surveillance detection and data link	P	FAATC	T	---	P	Validated during terminal OT&E.

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
	coverage shall include a slant range of 0.5 to 55 nmi. (3.2.1.1.6.2.1.a.)						
1810	The Mode S envelope for enroute surveillance detection and data link coverage shall include a slant range of 0.5 to 255 nmi. (3.2.1.1.6.2.1.a.)	P	FAATC	T	4.6	P	
1820	The Mode S envelope for surveillance detection and data link coverage shall include 360 degrees azimuth coverage. (3.2.1.1.6.2.1.b.)	P	FAATC	T	4.5	P	
1830	The Mode S envelope for surveillance detection and data link coverage shall include altitude coverage to 100,000 feet. (3.2.1.1.6.2.1.c.)	P	FAATC	T	---	P	Validated in terminal OT&E.
1840	The Mode S envelope for surveillance detection and data link coverage shall include elevation coverage from 0.5 to 45 degrees, with respect to the horizontal plane tangent to the earth at the radar antenna. (3.2.1.1.6.2.1.d.)	P	FAATC	T	---	F	The Mode S is limited in the enroute back-to-back antenna, which has an upper elevation between 35-40 degrees.
1840	Verify that the surveillance data response time allocated to communications shall not exceed 0.300 seconds for the ARSR-3 + Mode S sensor site configuration as shown in Table 3.2.1.2.7.1.1-1.	I	---	D	---	---	Deferred.
1860	Verify that the surveillance data response time allocated to communications shall not exceed 0.300 seconds for the ARSR-4 + Mode S sensor site configuration as shown in Table 3.2.1.2.7.1.1-1.	I	---	D	---	---	Deferred.
1880	Verify that the surveillance data response time allocated to communications shall not exceed 0.300 seconds for the Mode S Stand-alone sensor site configuration as shown in Table 3.2.1.2.7.1.1-1.	I	FAATC	T	5.3	P	Validated in Mode S/CD-2 configuration.
1900	The Mode S terminal sensor shall update surveillance reports on all targets within the detection envelope every antenna scan. (3.2.1.1.6.2.7)	P	FAATC	T	---	P	Validated during terminal OT&E.

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
1910	The Mode S enroute sensor shall update surveillance reports on all targets within the detection envelope twice per antenna scan when operating with a back-to-back beacon antenna, except when Mode 4 is using the front face antenna. (3.2.1.1.6.2.7)	P	---	D	---	---	Deferred.
1940	Verify that the surveillance data response time allocated to the ACCC in the ACF (AAS) shall not exceed 1.600 seconds for the ARSR-3 + Mode S sensor site configuration as shown in Table 3.2.1.2.7.1.1-1.	I	---	D	---	---	Deferred.
1960	Verify that the surveillance data response time allocated to the ACCC in the ACF (AAS) shall not exceed 1.600 seconds for the ARSR-4 + Mode S sensor site configuration as shown in Table 3.2.1.2.7.1.1-1.	I	---	D	---	---	Deferred.
1980	Verify that the surveillance data response time allocated to the ACCC in the ACF (AAS) shall not exceed 1.600 seconds for the Mode S Stand-alone sensor site configuration as shown in Table 3.2.1.2.7.1.1-1.	I	---	D	---	---	Deferred.
2000	The NAS shall provide enroute cooperative surveillance coverage from 6,000 feet MSL, up to and including 60,000 feet over non-mountainous terrain, and from 6,000 feet MSL or MEA, whichever is higher, to 60,000 feet in mountainous terrain. (3.2.1.2.7.4.b.)	P	Key Site	T	6.2	P	
2040	Verify that the surveillance data response time allocated to the System Reserve shall not exceed 0.100 seconds for the ARSR-3 + Mode S sensor site configuration as shown in Table 3.2.1.2.7.1.1-1. System Reserve may be allocated as specific siting requirements dictate. Most sensor site allocations are based on the provisions for including a tracker, either beacon	I	---	D	---	---	

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
	tracking or an integrated search/beacon tracking function at the sensor site. Sensor site allocations of the throughput lines are based on these data gathering times.						
2060	Verify that the surveillance data response time allocated to the System Reserve shall not exceed 0.100 seconds for the ARSR-4 + Mode S sensor site configuration as shown in Table 3.2.1.2.7.1.1-1. System Reserve may be allocated as specific siting requirements dictate. Most sensor site allocations are based on the provisions for including a tracker, either beacon tracking or an integrated search/beacon tracking function at the sensor site. Sensor site allocations of the throughput lines are based on these data gathering times.	I	---	D	---	---	
2080	Verify that the surveillance data response time allocated to the System Reserve shall not exceed 0.100 seconds for the Mode S Stand-alone sensor site configuration as shown in Table 3.2.1.2.7.1.1-1. System Reserve may be allocated as specific siting requirements dictate. Most sensor site allocations are based on the provisions for including a tracker, either beacon tracking or an integrated search/beacon tracking function at the sensor site. Sensor site allocations of the throughput lines are based on these data gathering times.	I	---	D	---	---	Deferred.
2350	Verify that the surveillance network shall display aircraft positions, relative to the aircraft actual position over the ground, within 2.04 nmi for enroute airspace.	I	---	---	5.2	---	
2400	Verify that NAS shall provide independent surveillance coverage for enroute ATCRBS cooperative aircraft	I	Key Site (Parker, CO)	T	6.2	P	

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
	from 6,000 feet MSL over non-mountainous terrain.						
2440	Verify that NAS shall provide independent surveillance coverage for enroute Mode S cooperative aircraft from 6,000 feet MSL over non-mountainous terrain.	I	Key Site (Parker, CO)	T	6.2	P	
2480	Verify that NAS shall provide independent surveillance coverage for enroute Mode S cooperative aircraft from 6,000 feet MSL or MEA, whichever is higher, in mountainous terrain.	I	Key Site	T	6.2	P	
2520	Verify that NAS shall provide independent surveillance coverage for enroute ATCRBS cooperative aircraft from 6,000 feet MSL or MEA, whichever is higher, in mountainous terrain.	I	Key Site	T	6.2	P	
2630	Verify that the surveillance network shall update data at least once every 12.1 seconds for enroute airspace.	I	FAATC	T	5.2	P	
2665	Verify that the surveillance network shall update data at least once every 12.1 seconds for sovereignty airspace.	I	FAATC	T	5.2	P	
3190	Verify that Mode S shall be capable of processing requests for military beacon interrogations (Mode 4).	I	---	D	---	---	
3220	Verify that Mode S shall be capable of receiving responses from military beacon interrogations (Mode 4).	I	---	D	---	---	
3230	Verify that Mode S shall be capable of routing responses from military beacon interrogations (Mode 4).	I	---	D	---	---	
3270	Verify that Mode S shall be capable of routing responses from ATCRBS Mode 2 beacon interrogations.	I	---	D	---	---	
3310	Verify that Mode S shall be capable of routing responses from ATCRBS Mode 3A beacon interrogations.	I	FAATC	T	5.2	P	
3350	Verify that Mode S shall be capable of routing responses from ATCRBS Mode B beacon interrogations.	I	---	D	---	---	
3390	Verify that Mode S shall be capable of	I	FAATC	T	5.2	P	

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
	routing responses from ATCRBS Mode C beacon interrogations.						
3430	Verify that Mode S shall be capable of routing responses from ATCRBS Mode D beacon interrogations.	I	---	D	---	---	
3500	Verify that Mode S sensor shall be capable of operating in an enroute stand-alone mode.	I	FAATC	T	5.4	P	
3540	Verify that Mode S sensor shall be capable of operating with an enroute (ARSR-3) search radar.	I	---	D	---	---	Deferred ARSR-3 configuration.
3550	Verify that Mode S sensor shall be capable of operating with an enroute (ARSR-4) search radar.	I	---	D	---	---	Deferred ARSR-4 configuration.
3560	Verify that Mode S sensor shall process beacon data from all detected targets to provide positional data with an update rate specified in 3.2.1.1.6.2.7.	I	FAATC	T	5.2	---	
3570	Verify that Mode S sensor shall process beacon data from all detected targets to provide identification data with an update rate specified in 3.2.1.1.6.2.7.	I	FAATC	T	5.2	---	
3580	Verify that Mode S sensor shall process beacon data from all detected targets to provide positional data with the timeliness specified in 3.2.1.1.6.2.8.	I	FAATC	T	5.2	---	
3590	Verify that Mode S sensor shall process beacon data from all detected targets to provide identification data with the timeliness specified in 3.2.1.1.6.2.8.	I	FAATC	T	5.2	---	
3615	Verify that when collocated with a (ARSR-3) search radar, the Mode S shall receive digitized search radar data.	I	---	D	---	---	Deferred ARSR-3 configuration.
3618	Verify that when collocated with a (ARSR-4) search radar, the Mode S shall receive digitized search radar data.	I	---	D	---	---	Deferred ARSR-4 configuration.
3635	Verify that when collocated with a (ARSR-3) search radar, the Mode S shall perform a search/beacon correlation (merge) function.	I	---	D	---	---	Deferred ARSR-3 configuration.
3638	Verify that when collocated with a (ARSR-4) search radar, the Mode S	I	---	D	---	---	Deferred ARSR-4 configuration.

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
	shall perform a search/beacon correlation (merge) function.						
3655	Verify that when collocated with a (ARSR-3) search radar, the Mode S shall output a combined data stream.	I	---	D	---	---	Deferred ARSR-3 configuration.
3658	Verify that when collocated with a (ARSR-4) search radar, the Mode S shall output a combined data stream.	I	---	D	---	---	Deferred ARSR-4 configuration.
3675	Verify that when collocated with a (ARSR-3) search radar, the Mode S shall receive digitized search radar data, perform search/beacon correlation (merge), and output a combined data stream at the update rate specified in 3.2.1.1.6.2.7.	I	---	D	---	---	Deferred ARSR-3 configuration.
3678	Verify that when collocated with a (ARSR-4) search radar, the Mode S shall receive digitized search radar data, perform search/beacon correlation (merge), and output a combined data stream at the update rate specified in 3.2.1.1.6.2.7.	I	---	D	---	---	Deferred ARSR-4 configuration.
3695	Verify that when collocated with a (ARSR-3) search radar, the Mode S shall receive digitized search radar data, perform search/beacon correlation (merge), and output a combined data stream with a timeliness specified in 3.2.1.1.6.2.8.	I	---	D	---	---	Deferred ARSR-3 configuration.
3698	Verify that when collocated with a (ARSR-4) search radar, the Mode S shall receive digitized search radar data, perform search/beacon correlation (merge), and output a combined data stream with a timeliness specified in 3.2.1.1.6.2.8.	I	---	D	---	---	Deferred ARSR-4 configuration.
4002	Verify that Mode S sensor shall accept an input (Extended Length Message Uplink) from the ACCC as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	
4004	Verify that Mode S sensor shall accept an input (Standard Uplink) from the	I	---	D	---	---	

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
	ACCC as specified in Table 3.2.1.1.6.3-1.						
4006	Verify that Mode S sensor shall accept an input (Test Message) from the ACCC as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	
4010	Verify that Mode S sensor shall prepare an output (Antenna Sync, Message Number: N063A1/0005) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	Unknown message type.
4014	Verify that Mode S sensor shall prepare an output (Beacon Radar Data, Message Number: N063A1/002) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.2	P	
4016	Verify that Mode S sensor shall prepare an output (Beacon Real Time Quality Control-RTQC) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.2	P	
4018	Verify that Mode S sensor shall prepare an output (Beacon Status) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.2	P	
4020	Verify that Mode S sensor shall prepare an output (Beacon Strobe) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.2	P	
4024	Verify that Mode S sensor shall prepare an output (Beacon/Radar Reinforced Data, Message Number: N063A2/002) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.2	P	
4028	Verify that Mode S sensor shall prepare an output (Beacon/Radar Status, Message Number: N063A6/002) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.2	P	
4032	Verify that Mode S sensor shall prepare an output (Digitized Search Radar Data, Message Number: N064A1/004) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.2	P	
4034	Verify that Mode S sensor shall prepare an output (Extended Length Message Down Link) to the ACCC as specified in	I	---	D	---	---	

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
	Table 3.2.1.1.6.3-1.						
4038	Verify that Mode S sensor shall prepare an output (Radar Real Time Quality Control-RTQC, Message Number: N064A2/006) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.2	P	
4040	Verify that Mode S sensor shall prepare an output (Radar Real Time Quality Control-RTQC, Message Number: N064A2/008) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	Military format (w/height info).
4042	Verify that Mode S sensor shall prepare an output (Radar Strobe) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.2	P	
4044	Verify that Mode S sensor shall prepare an output (Standard Down Link) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	
4046	Verify that Mode S sensor shall prepare an output (Synch/Idle) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.2	P	
4048	Verify that Mode S sensor shall prepare an output (Test Response Message) to the ACCC as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	
4050	Verify that Mode S sensor shall accept an input (Digitized Search Radar Data) from an ARSR-3 as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	Deferred ARSR-3 configuration.
4052	Verify that Mode S sensor shall accept an input (Radar Status Message) from an ARSR-3 as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	Deferred ARSR-3 configuration.
4054	Verify that Mode S sensor shall accept an input (Radar Strobe) from an ARSR-3 as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	Deferred ARSR-3 configuration.
4056	Verify that Mode S sensor shall accept an input (Radar Status Message) from an ARSR-4 as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	Deferred ARSR-4 configuration.
4058	Verify that Mode S sensor shall accept	I	---	D	---	---	Deferred ARSR-4

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
	an input (Radar Status Message) from an ARSR-4 as specified in Table 3.2.1.1.6.3-1.						configuration.
4060	Verify that Mode S sensor shall accept an input (Radar Target) from an ARSR-4 as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	Deferred ARSR-4 configuration.
4062	Verify that Mode S sensor shall accept an input (Radar/Height) from an ARSR-4 as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	Deferred ARSR-4 configuration.
4064	Verify that Mode S sensor shall accept an input (Real Time Quality Control-RTQC) from an ARSR-4 as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	Deferred ARSR-4 configuration.
4066	Verify that Mode S sensor shall prepare an output (TBD Message) to an ARSR-4 as specified in Table 3.2.1.1.6.3-1.	I	---	D	---	---	Deferred ARSR-4 configuration.
4092	Verify that Mode S sensor shall accept an input (Radar Status Message) from a Digitizer as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.1	P	
4094	Verify that Mode S sensor shall accept an input (Radar Strobe) from a Digitizer as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.1	P	
4096	Verify that Mode S sensor shall accept an input (Radar Target) from a Digitizer as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.1	P	
4098	Verify that Mode S sensor shall accept an input (Real Time Quality Control-RTQC) from a Digitizer as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.1	P	
4304	Verify that a surveillance output (Antenna Sync, Message Number: N151/005) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.11.	I	---	D	---	---	Unknown message type.
4308	Verify that a surveillance output (Beacon Radar Data) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.11.	I	FAATC	T	5.3	P	10 second scan rate, 255 nmi.
4312	Verify that a surveillance output (Beacon	I	FAATC	T	5.4	P	10 second scan rate, 255

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
	Status) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.11.						nmi.
4314	Verify that a surveillance output (Beacon Strobe) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.11.	I	FAATC	T	5.3	P	Suppressed by Mode S.
4318	Verify that a surveillance output (Beacon/Radar Reinforced Data, Message Number: N063A2/002) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.11.	I	FAATC	T	5.3	P	10 second scan rate, 255 nmi.
4322	Verify that a surveillance output (Beacon/Radar Status, Message Number: N063A2/002) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.11.	I	FAATC	T	5.3	P	10 second scan rate, 255 nmi.
4326	Verify that a surveillance output (Digitized Search Radar Data, Message Number: N064A1/004) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.11.	I	FAATC	T	5.3	P	10 second scan rate, 255 nmi.
4330	Verify that a surveillance output (Radar Real Time Quality Control-RTQC, Message Number: N064A2/006) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.11.	I	FAATC	T	5.3	P	10 second scan rate, 255 nmi.
4332	Verify that a surveillance output (Radar Real Time Quality Control-RTQC, Message Number: N064A2/008) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.11.	I	---	D	---	---	Military format (w/height info).
4334	Verify that a surveillance output (Radar Strobe) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.11.	I	---	D	---	---	
4336	Verify that a surveillance output (Sync/Idle) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.11.	I	FAATC	T	5.3	P	10 second scan rate, 250 nmi.
4338	Verify that a surveillance output (TBD Message) to ARSR-4 shall be subject to the capacities as specified in 3.2.1.1.6.2.11.	I	---	D	---	---	
4348	Verify that a surveillance output	I	FAATC	T	5.3	P	

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
	(Mode C Interrogation) to an ATCRBS Transponder shall be subject to the capacities as specified in 3.2.1.1.6.2.11.						
4350	Verify that a surveillance output (Mode 3/A Interrogation) to an ATCRBS Transponder shall be subject to the capacities as specified in 3.2.1.1.6.2.11.	I	FAATC	T	5.3	P	
4402	Verify that a data link output (Extended Length Message Down Link) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.12, within the data link peaking performance specified in 3.2.1.1.6.2.13.	I	---	D	---	---	
4404	Verify that a data link output (Standard Down Link) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.12, within the data link peaking performance specified in 3.2.1.1.6.2.13.	I	---	D	---	---	
4406	Verify that a data link output (Test Response Message) to ACCC shall be subject to the capacities as specified in 3.2.1.1.6.2.12, within the data link peaking performance specified in 3.2.1.1.6.2.13.	I	---	D	---	---	
4408	Verify that a data link output (Aircraft Position) to an MCP shall be subject to the capacities as specified in 3.2.1.1.6.2.12, within the data link peaking performance specified in 3.2.1.1.6.2.13.	I	---	D	---	---	
4410	Verify that a data link output (Aircraft State) to an MCP shall be subject to the capacities as specified in 3.2.1.1.6.2.12, within the data link peaking performance specified in 3.2.1.1.6.2.13.	I	---	D	---	---	
4412	Verify that a data link output (Data Link Capability) to an MCP shall be subject to the capacities as specified in 3.2.1.1.6.2.12, within the data link peaking performance specified in 3.2.1.1.6.2.13.	I	---	D	---	---	

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
4414	Verify that a data link output (Message Rejection Notice with Sensor IDs) to an MCP shall be subject to the capacities as specified in 3.2.1.1.6.2.12, within the data link peaking performance specified in 3.2.1.1.6.2.13.	I	---	D	---	---	
4416	Verify that a data link output (Track Drop) to an MCP shall be subject to the capacities as specified in 3.2.1.1.6.2.12, within the data link peaking performance specified in 3.2.1.1.6.2.13.	I	---	D	---	---	
4418	Verify that a data link output (Uplink Delivery Notice (#1)) to an MCP shall be subject to the capacities as specified in 3.2.1.1.6.2.12, within the data link peaking performance specified in 3.2.1.1.6.2.13.	I	---	D	---	---	
4900	Verify that the Mode S shall have built in remote monitoring elements capable of monitoring subsystem status.	I	FAATC	T	5.3	---	
4950	Verify that the Mode S shall have built in remote monitoring elements capable of monitoring subsystem alarms.	I	FAATC	T	5.3	---	
5000	Verify that the Mode S shall be capable of supplying operational status as specified in Table 3.2.1.1.6.3-1.	I	FAATC	T	5.3	---	
5630	Verify the scan rate of the Mode S sensor shall be identical to that of the associated (ARSR-3) primary radar.	I	---	D	---	---	Deferred ARSR-3 configuration.
5640	Verify the scan rate of the Mode S sensor shall be identical to that of the associated (ARSR-4) primary radar.	I	---	D	---	---	Deferred ARSR-4 configuration.
5650	Verify the scan rate for stand-alone Mode S sensors shall be 12 seconds +1.33 or –1.09 seconds.	I	FAATC	T	5.4	P	
5850	Verify that the Mode S shall update reports on all targets within the detection envelope twice per antenna scan when operating with a back-to-back beacon antenna, except when Mode 4 is using the front face.	I	---	D	5.3	---	The Mode S is limited in the enroute back-to-back antenna, which has an upper elevation between 35-40 degrees.
5935	Verify that surveillance data, after	I	FAATC	---	5.4	P	

REQUIREMENT NO.	NAS-SS-1000 REQUIREMENT STATEMENT	TEST LEVEL	LOCATION	TEST METHOD	TEST PARAGRAPH	PASS / FAIL	COMMENT
	acquisition by the Mode S sensor antenna, shall be processed and available for dissemination, from the sensor to the destination specified in Table 3.2.1.1.6.3-1, no later than 1.300 seconds when acting as a stand-alone Mode S.						
5970	Verify that surveillance data, after acquisition by the Mode S sensor antenna, shall be processed and available for dissemination, from the sensor to the destination specified in Table 3.2.1.1.6.3-1, no later than 1.300 seconds when collocated with an enroute radar.	I	FAATC	T	5.3	P	
6050	Verify that all down link communication messages shall be delayed no more than 1/16 of a scan period from the time the message is received until it is available for transmission from the sensor to the destinations specified in Table 3.2.1.1.6.3-1.	I	Contractor Facility	T	---	P	Validated during DT&E testing, SDQ5.
7060	Verify that the Mode S shall interface functionally as shown in Figure 3.2.1.1.6.3-3. The Mode S functional interfaces are defined in Table 3.2.1.1.6.3-1.	I	---	D	---	---	Deferred ARSR-3/-4 configuration.
7070	Verify that the Mode S shall interface physically as shown in Figure 3.2.1.1.6.3-3.	I	---	D	---	---	Deferred ARSR-3/-4 configuration.
7080	Verify that the Mode S shall interface functionally as shown in Figure 3.2.1.1.6.3-4. The Mode S functional interfaces are defined in Table 3.2.1.1.6.3-1.	I	FAATC	I	5.4	P	
7090	Verify that the Mode S shall interface physically as shown in Figure 3.2.1.1.6.3-4.	I	FAATC	I	5.4	P	

APPENDIX C

RADAR BEACON ANALYSIS TOOL (RBAT) OVERVIEW

Radar Beacon Analysis Tool User's Manual

C.1 OVERVIEW.

The Radar Beacon Analysis Tool (RBAT) is a set of radar analysis programs that can be used to analyze Common Digitizer (CD) files and Mode Select Beacon System (Mode S) files. The programs require Windows 3.1 and run on a personal computer (PC) as Windows applications. A math co-processor chip is required. An attached printer that can print 132 characters per line is needed to print the output listings and a graphics printer is needed to print the plots. A short description for each of the programs follows:

a. Beacon and Radar Coverage: Prints and plots the beacon and radar coverage for each cell. The coverage is defined as the minimum altitude and elevation angle for the cell.

b. Beacon and Radar Coverage Merge: Merges beacon and radar coverage listings and plots.

c. Beacon Code Swap Analysis: Analyzes Air Traffic Control Radar Beacon System (ATCRBS) beacon code swaps. The percentage is printed and range versus azimuth, range versus altitude, and azimuth versus altitude plots are provided for the ATCRBS beacon code swaps.

d. Beacon Code Swap Analysis Merge: Merges ATCRBS beacon code swap percentages and produces trend plots.

e. Beacon False Target Summary: Groups false targets into the ATCRBS/Mode S, split, ringaround, downlink reflection, pulse repetition frequency (PRF), uplink reflection, and other categories. The uplink reflections are used to calculate the location and orientation of the reflectors. Range versus azimuth, range versus elevation, and azimuth versus elevation plots are provided for false targets and beacon messages with ATCRBS identities (IDs) of 0000. A reflector plot is also provided.

f. Beacon False Target Summary Merge: Merges false target statistics and plots and produces trend plots.

g. Calibration Analysis: Analyzes the data extracted during calibration. Plots of the reply samples matrix and the reply failure code counts are provided.

h. Channel Management Statistics: Analyzes the performance of the channel management function in the Mode S sensor. Statistics are given individually for each target and combined into totals for all the targets. Lost channel time is computed. Plots of the individual roll call periods are provided, both actual and expected.

i. Channel Management Statistics Merge: Merges channel management statistics and produces trend plots.

j. Communications Print: Prints the Communication messages that are transferred to and from the Mode S sensor.

k. Conflict Analysis: Analyzes conflicts, where two tracks are in conflict if they are in each other's user specified range and azimuth windows. The same statistics as given by Surveillance Analysis (SA) are provided for each conflict. Plots of the conflicts are also provided.

l. Conflict Analysis Merge: Merges conflict statistics and produces trend plots.

m. Convert Mode S File to CD File: Creates an output CD file using the disseminated messages extracted on the Mode S file.

n. Data Link Statistics: Analyzes the performance of the data link function in the Mode S sensor. Statistics are given individually for each target and combined into totals for all the targets. Plots are provided which give the delivery time statistics for the messages.

o. Data Link Statistics Merge: Merges data link statistics and produces trend plots.

p. Disseminated Message Summary: Summarizes the ATCRBS and Mode S reports which are disseminated and those which are not. Counts are given for each scan and the reports which are not disseminated are plotted.

q. Disseminated Message Summary Merge: Merges correlated and uncorrelated report statistics and produces trend plots.

r. Filfile: Filters the categories on the input Mode S file and creates an output Mode S file that contain all the categories that pass the filter. These categories can also be listed in hexadecimal and counted. Time and category type filters are available.

s. Filter: Filters the messages on the input CD file and creates an output CD file that contains all the messages that pass the filter. Time, range, azimuth, altitude, elevation angle, ATCRBS ID, Mode S ID, surveillance file number, channel, ATCRBS/Mode S, message type, and bit field filters are available.

t. Fixed Transponder Accuracy: Analyzes the range and azimuth accuracy of the beacon messages for a specified fixed transponder. The reference range and azimuth positions are input by the user.

u. Fixed Transponder Accuracy Merge: Merges range and azimuth accuracy statistics and plots for the fixed transponders and produces trend plots.

v. FRUIT Analysis: Calculates the ATCRBS and Mode S FRUIT rates coming in to the Mode S sensor. Statistics are given for each sector and combined into totals for all the sectors. These statistics are given every minute for the duration of the filter time interval. These FRUIT rates are also plotted.

w. FRUIT Analysis Merge: Merges FRUIT rate statistics and produces trend plots.

x. Miscellaneous Print: Prints miscellaneous records on the Mode S file. Some examples are performance monitoring, active message list, site adaptable data, scan data, duplicate address alert table, collimation difference table, ATCRBS radar range mask, channel configuration table, and remote monitoring system messages.

y. Monopulse Analysis: Analyzes the distribution of monopulse values for a fixed transponder. Plots of monopulse versus antenna azimuth, azimuth error versus antenna azimuth, the absolute value of azimuth error versus antenna azimuth, mean and standard deviation, the monopulse table of the Mode S sensor, and scatter plots of the raw data points are provided.

z. Moving Surveillance File Filter: Filters the categories on the input Mode S file and creates an output Mode S file that contains all the categories that pass the filter. The filter is a user-specified range and azimuth interval around a user-specified surveillance file.

aa. Moving Track Filter: Filters the messages on the input CD file and creates an output CD file that contains all the messages that pass the filter. The filter is a user-specified range and azimuth interval around a user-specified track. The track numbers are those that are given on the SA summary output.

ab. Nine Point: Analyzes the range and azimuth accuracy of the beacon messages for all the targets which have Mode S IDs or are ATCRBS with discrete ATCRBS IDs. The reference range and azimuth positions are determined using a nine point curve fit centered on the beacon message.

ac. Nine Point Merge: Merges range and azimuth accuracy statistics and plots and produces trend plots.

ad. Peak Loading: Prints and plots the wedges, sectors, and quadrants which contain target counts in excess of their thresholds.

ae. Playback: Displays messages with the following options:

1. alphanumerics (track number) on or off
2. x and y grid
3. range rings
4. direction (forward or reverse)
5. mode (single scan or continuous)
6. speed (normal, fast, or slow)
7. center of plot area
8. length of plot area
9. scan number of plot area
10. zoom factor of plot area
11. grid spacing of plot
12. scan history of targets on plot

The plot area can be scrolled using the horizontal and vertical scroll bars and the center and length edit boxes. The displayed targets can be moved forward and backward in time by using the scan scroll bar.

af. Plot: Plots data from a plot file that is output by one of the programs.

ag. Print: Prints data from an output listing file that is output by one of the programs.

ah. Radar Analysis: Analyzes search performance on all tracks. Statistics are given individually for each track and combined for all the tracks. A range versus azimuth plot is provided that contains track initiations, coasts, and drops.

ai. Radar Analysis Merge: Merges radar statistics and produces trend plots.

aj. Reflectors: Prints, plots, and stores the Mode S site adapted reflectors. The stored reflectors can be used by the Beacon False Target Summary program.

ak. Reply to Reply Processing: Implements to ATCRBS Reply to Reply Processing function in FAA-E-2716 and correlates the reports built by the analysis program to the reports built by the Mode S sensor.

al. Scan by Scan Plot: Plots a user-specified number of scans of messages per plot. The user can also specify the number of scans between successive plots.

am. Scan Summary: Counts the number of messages in various categories for each scan. It also gives the initial system status and any changes in status.

an. Scroll: Displays data from an output listing file that is output by one of the programs. The user can scroll both vertically and horizontally through the file.

ao. Set Defaults: Enables the user to set up default user parameters for each known site or sensor and to set up default user parameters that will be used for any unknown site or sensor.

ap. Surveillance Analysis: Analyzes beacon and search performance on all beacon tracks. Statistics are given individually for each track and combined into ATCRBS, Mode S, and total categories. Range versus azimuth, range versus altitude, and azimuth versus altitude plots are provided which contain track initiations, coasts, and drops.

aq. Surveillance Analysis Merge: Merges beacon and radar statistics and produces trend plots.

ar. Surveillance File Analysis: Analyzes the surveillance file and hence the tracking function of the Mode S sensor. Statistics are given individually for each track and combined into ATCRBS, Mode S, and total categories.

as. Surveillance File Plot: Plots surveillance files on a Mode S file.

at. Surveillance Filter: Filters the messages on the input Mode S file and creates an output Mode S file that contains all the messages that pass the filter. Time, range, azimuth, altitude, elevation angle, ATCRBS ID, Mode S ID, surveillance file number, flight status, facility ID, ATCRBS/Mode S, message type, and category type filters are available.

au. Surveillance Print: Prints the replies, reports, surveillance files, and disseminated reports.

av. Surveillance Print and Plot: Prints, plots, and counts the messages. Range versus azimuth, range versus altitude, and azimuth versus altitude plots are provided which contain the messages that pass the filter. Time, range, azimuth, altitude, elevation angle, ATCRBS ID, Mode S ID, surveillance file number, channel, ATCRBS/Mode S, and message type filters are available.

aw. Traffic Information Service (TIS) Analysis: Analyzes the detection of intruders by the real time TIS function and the reliability of the fields reported in the TIS advisory messages. Statistics are given individually for each client and combined for all the clients. Plots which simulate the TIS displays in the client aircraft are provided.

ax. TIS Analysis Merge: Merges TIS Analysis statistics and produces trend plots.

ay. View: Displays one full page of data per screen. The data is input from an output listing file that is output by one of the programs. Thirteen of the above programs are merge programs. They merge the data from several tests together. A test is a single recording of a radar site. A likely way to use the merge programs is to run one test every day of the month for a given site. Each day is assigned a test number, where the number assigned might be the day of the month. Then at the end of the month all the tests can be merged. Another way to use the merge programs is to analyze data from multiple sites and assign a test number to every site. The merge programs have three effects. First, there will be better coverage. Second, the statistics will be more reliable. Third, trends in the statistics can be shown.

C.2 TIME CALCULATION.

a. CD Files: The time is recorded in either .1-second or 1/128-second increments for each message on the CD file. The Surveillance Advanced Message Formats (SAMF) contain both the time that the target was updated and the time that the message was recorded. CD formats other than SAMF contain only the time that the message was recorded. If there are delays, the difference between the two times can be significant. Since it is essential that the time be accurate, a method is needed to compute the time that the target is updated. Each message (except Status) contains the azimuth of the target. If the time that the antenna crossed northmark is known, the time each target is updated can be determined from its azimuth. This is done using the equation time (update) = time (northmark) + azimuth/antenna rate. Therefore, the problem is reduced to determining the time at northmark and determining the antenna rate. Both these problems can be solved. The time at northmark can be determined using the beacon sector mark, search sector mark, beacon RTQC, or search RTQC messages. These are called timing messages

and the choice of which timing message to use is specified by the user. The azimuth from the timing message and the antenna scan time are used to determine the time at northmark. This procedure works because the timing messages are delayed less than the other messages. The search RTQC timing messages for CD-1, CD-2, ARSR-3, or ARSR-4 radars also contain time-in-storage, which is a measure of the delay that did occur. The antenna scan time is computed using the recorded time of the timing messages averaged over the first ten consecutive scans. The antenna rate is equal to 360° divided by the antenna scan time.

b. Mode S Files: The time is recorded in 1/128 second increments for each category that is extracted on the Mode S file. Only ATCRBS replies, ATCRBS and Mode S reports, and ATCRBS and Mode S surveillance files contain the time that the target is updated. If there are delays, the difference between the two times can be significant. Since it is essential that the time be accurate, a method is needed to compute the time that the target is updated when the update time is not available. All of the surveillance categories contain the azimuth of the target. If the time that the antenna crossed northmark is known, the time each target is updated can be determined from its azimuth. This is done using the equation time (update) = time (northmark) + azimuth/antenna rate. Therefore, the problem is reduced to determining the time at northmark and determining the antenna rate. The antenna rate is recorded in the beginning of the file and the time at northmark is recorded every scan. The antenna rate is equal to 360° divided by the antenna scan time.

APPENDIX D

ARIES SCENARIO DESCRIPTIONS

SCENARIO DESCRIPTIONS

BASIC 41 (Surveillance Stress)

This scenario consists of 41 dynamic targets performing various types of maneuvers including straight line tracks, turning tracks, overtaking patterns, and crossing tracks. The purpose of this scenario is to gather baseline data on the sensor's ability to maintain tracking in many complex situations.

CAPACITY

This scenario begins as a light load and gradually builds to a 700 target per scan capacity load. The targets then move to the distribution defined in the FAA-E-2716 Specification, sections 3.3.2.5 and 3.3.2.5.1. It also incorporates the data link peaking scenario defined in NAS-SS-1000 section 3.2.1.1.6.3.13. The purpose of this scenario is to gather data on the sensor's ability to handle a capacity situation.

PROBABILITY OF DETECTION

These scenarios generate the simulated targets for the probability of detection (Pd) measurements. They will be used to establish the Pd baseline as a function of signal strength for no FRUIT and capacity FRUIT conditions. The terminal scenarios are each available for four different signal levels; -70, -73, -76, and -79 decibels below the level of a milliwatt (dBm).

(Terminal Version)

The scenario begins as a ring of 32 targets equally spaced every 11.25° at a range of 5 nautical miles (nmi). As the scenario begins, the targets start moving slightly clockwise (cw) and further in range at an approximate ground speed of 240 nmi/hour. The scenario ends after 10 minutes with each target at a range of 45 nmi, and 5.625° cw from original position. Of the 32 targets, 16 are discrete Air Traffic Control Radar Beacon System (ATCRBS) targets and 16 are Mode Select Beacon System (Mode S) targets. The ATCRBS and Mode S targets alternate every 11.25°.

(Enroute Version)

The enroute version is similar to the terminal except there are five rings of targets, each spaced 50 nmi apart.

REAL WORLD

These scenarios are designed to duplicate the flight parameters of aircraft in actual terminal or enroute environment. The data used to generate the scenarios will be extracted at selected operational Terminal Radar Approach Control (TRACON) and Air Route Traffic Control Center (ARTCC) facilities. The purpose of these scenarios is to determine the sensor's surveillance and data link performance, using realistic simulations.

UPLINK REFLECTION

The uplink reflection scenario is designed to test the sensor's reflection algorithms. The scenario consists of 16 pairs of targets; each pair consists of a reflected target and a true

target. The 16 reflecting surfaces, 4 in each quadrant, which could cause the reflections, have been calculated. A reflector map, containing the range, orientation, and azimuth of the 16 reflected target quadrant and true target quadrant, is tested, e.g., a real target in the 0-90° quadrant shall have a reflected false target generated in the 0-90°, 90-180°, 180-270°, and 270-360° quadrants using four different reflectors.

DOWNLINK REFLECTION

The downlink reflection scenario simulates ground-bounce replies and is designed to test the sensor's adaptive threshold circuitry. Pairs of moving targets will be generated (same azimuth but different range). The range difference of each pair will be varied from completely separated to fully overlapped. The true reply's intensity will be 20 decibel (dB) greater than that of the ground-bounce reply.

FRUIT

Various False Replies Unsynchronized in Time (FRUIT) scenarios will be employed with FRUIT levels varying from no FRUIT to heavy FRUIT (40 kilos (k)/second (sec) ATCRBS, 640/sec Mode S).

APPENDIX E

IBI/NADIF TEST DATA SUMMARIES

IBI/NADIF Radar Analysis Comparison Chart
Location: Parker, Colorado

File Name (filename.ext)		ib1201.ibi	ib1201ct.ibi	ia1202am.ibi	ia1205am.ibi	ibia_am.c06	ibia_pm.c06
File Date (mm/dd/yy)		12/01/94	12/01/94	12/02/94	12/05/94	12/06/94	12/06/94
Beacon Source		ibib	ibib	ibia	ibia	ibia	ibia
Beacon Antenna Tilt (degrees)		2.0	2.0	2.0	2.0	2.0	2.0
Search Antenna tilt (degrees)		2.0	2.0	2.0	2.0	2.0	2.0
SLS/ISLS		SLS	SLS	SLS	SLS	SLS	SLS
Dir/Omni Power into Ant (peak watts)							
STC Value (dB)							
Beacon False Target Analysis (BFTA)							
Note: Goal is not pass/fail.	**>Goal<**						
Total Number of Discrete Code Target Reports		51533	45285	39461	33591	90530	69889
False Target Report %	**< 1.5**	0.37	0.90	0.61	0.10	0.18	0.25
Split %	**< 0.5**	0.05	0.25	0.47	0.02	0.06	0.05
Ringaround %	**< 0.2**	0.19	0.09	0.03	0.01	0.04	0.08
Downlink Reflection %	**< 0.2**	0.01	0.00	0.00	0.00	0.00	0.00
PRF %	**< 0.2**	0.01	0.01	0.01	0.02	0.03	0.02
Uplink Reflection %	**< 0.2**	0.02	0.00	0.00	0.01	0.01	0.04
Other %	**< 0.2**	0.11	0.54	0.10	0.02	0.04	0.06
ATCRBS ID 0000 TGT RPT %	**< 0.5**	0.44	0.69	0.48	0.32	0.20	0.10
Surveillance Analysis (SA)							
Pd Beacon %	**> 97**	98.57	98.48	98.79	98.94	99.42	99.46
Pd Search %	**> 70**	67.64	73.89	75.99	67.20	70.06	68.76
Pd Total (%)	**> 97**	99.21	99.39	99.53	99.34	99.61	99.69
Identity Reliability (%)	**> 95**	99.32	99.02	99.31	99.63	99.73	99.82
Identity Validity (%)	**> 95**	98.42	97.79	98.17	99.09	99.31	99.61
Altitude Reliability (%)	**> 95**	99.39	99.23	99.33	99.58	99.76	99.83
Altitude Validity (%)	**> 95**	98.51	97.91	98.33	99.26	99.37	99.66
Beacon Hits	**> 29**	312	30.2	30.9	30.6	31.4	32.7
Radar Reinforcement (%)	**> 70**	67.95	74.07	76.15	67.48	70.26	68.88
Search Collimation (%)	**> 95**	99.98	99.97	99.97	99.95	99.98	99.96
Range Error (nmi)	**< 0.2**	0.076	0.077	0.075	0.075	0.071	0.070
Azimuth Error (degrees)	**< 0.35**	0.217	0.195	0.211	0.217	0.198	0.206
Number of Tracks in Statistics		612	560	503	342	551	454
Permanent Echo Accuracy (PEA)							
Mode 3/A Code		**1273**	**1273**	**1273**	**1273**	**1273**	**1273**
Single Report ATCRBS Update %	**> 97**	99.449	99.721	99.617	95.066	100.00	99.876
Range Error Mean (nmi)	**< 0.13**	0.012	0.012	0.012	0.012	0.012	0.012
Range Error Std-Dev (nmi)	**+/- 0.13**	0.000	0.000	0.000	0.000	0.000	0.000
Azimuth Error Mean (degrees)	**< 0.2**	0.013	0.034	0.050	-0.024	0.005	0.004
Azimuth Error Std-Dev (degrees)	**+/- 0.2**	0.053	0.054	0.054	0.137	0.058	0.059

IBI/Open Array Radar Analysis Comparison Chart
Location: Parker, Colorado

File Name (filename.ext)		iaeval1. 116	iaeval2. 116	iaeval4. 116	iaeval5. 116	iaeval6. 116	iaeval7. 116
File Date (mm/dd/yy)		04/25/96	04/25/96	04/25/96	04/25/96	04/25/96	04/25/96
Beacon Antenna Tilt (degrees)		0.0	0.0	0.0	0.0	0.0	0.0
Search Antenna tilt (degrees)		+ 1.5	+ 1.5	+ 1.5	+ 1.5	+ 1.5	+ 1.5
SLS/ISLS		SLS	SLS	SLS	SLS	SLS	SLS
Dir/Omni Power into Ant (peak watts)		200/600	200/600	200/600	200/600	200/600	200/600
STC Value (dB)		52.5	52.5	52.5	52.5	52.5	52.5
Comments: CPMEs were readjusted for both transmitter power and receiver sensitivity.		RAW	RAW	RAW	RAW	RAW	RAW
Beacon False Target Analysis (BFTA)							
Note: Goal is not pass/fail.	**>Goal<**						
Total Number of Discrete Code Target Reports		15739	13290	17480	15794	16996	16582
False Target Report %	**< 3.6**	0.01	0.04	0.02	0.01	0.04	0.04
Split %	**< 0.2**	0.01	0.01	0.01	0.01	0.01	0.02
Ringaround %	**< 1.0**	0.00	0.00	0.00	0.01	0.00	0.01
Downlink Reflection %	**< 1.0**	0.00	0.00	0.01	0.00	0.00	0.00
PRF %	**< 0.2**	0.00	0.00	0.01	0.00	0.00	0.00
Uplink Reflection %	**< 1.0**	0.00	0.00	0.00	0.00	0.00	0.00
Other %	**< 0.2**	0.00	0.03	0.01	0.00	0.03	0.01
ATCRBS ID 0000 TGT RPT %	**< 0.5**	0.27	0.47	0.31	0.25	0.17	0.11
Surveillance Analysis (SA)							
Pd Beacon %	**> 97**	99.18	99.08	99.59	99.47	99.11	99.52
Pd Search %	**> 80**	82.21	81.72	85.63	82.91	81.71	83.06
Pd Total (%)	**> 97**	99.68	99.60	99.79	99.80	99.65	99.83
Identity Reliability (%)	**> 97**	99.89	99.71	99.79	99.81	99.89	99.82
Identity Validity (%)	**> 97**	99.38	98.84	98.94	98.99	99.63	99.45
Altitude Reliability (%)	**> 97**	99.58	99.52	99.85	99.80	99.77	99.80
Altitude Validity (%)	**> 97**	99.34	98.92	99.59	99.53	99.59	99.47
Beacon Hits	**> 20**	46.1	45.5	46.2	45.9	46.4	46.8
Radar Reinforcement (%)	**> 80**	82.35	81.93	85.75	83.02	81.88	83.09
Search Collimation (%)	**> 90**	99.95	99.97	99.97	99.99	99.98	99.93
Range Error (nmi)	**< 0.0156**	0.068	0.067	0.066	0.068	0.069	0.068
Azimuth Error (degrees)	**< 0.176**	0.162	0.151	0.151	0.155	0.162	0.152
Number of Tracks in Statistics		208	169	190	185	192	192
Permanent Echo Accuracy (PEA)							
Mode 3/A Code		**1273**	**1273**	**1273**	**1273**	**1273**	**1273**
Single Report ATCRBS Update %	**> 97**	100.00	100.00	100.00	100.00	99.444	100.00
Range Error Mean (nmi)	**< 0.0313**	0.012	0.012	0.012	0.012	0.012	0.012
Range Error Std-Dev (nmi)	**+/- 0.031**	0.000	0.000	0.000	0.000	0.000	0.000
Azimuth Error Mean (degrees)	**< 0.176**	0.167	0.177	0.177	0.190	0.196	0.196
Azimuth Error Std-Dev (degrees)	**+/- 0.176**	0.061	0.062	0.065	0.056	0.109	0.131